ONLINE LABORATORY INTRODUCTIONS TO PROMOTE STUDENT INTERACTIONS WITH TWO SCIENCE AND ENGINEERING PRACTICES OF THE NEXT GENERATION SCIENCE STANDARDS

by

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DEDICATION

I dedicate this dissertation to my two children, Anna and Joseph Howlett, who remind me daily how important problem solving and life-long learning are.

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I would like to acknowledge all those who helped me to achieve my educational goals; including my family, professors, colleagues, and friends.

ABSTRACT

Online science courses are becoming increasingly available to K-12 students in the United States. With the utilization of these courses, it is important to facilitate student completion of laboratories as well as student interest in and use of the science and engineering practices (SEPs) of the Next Generation Science Standards (NGSS). This exploratory research provided online laboratory introductions to help students interact with the content and the instructor. The research studied if the laboratory introductions led students to ask questions about laboratories, complete laboratories, and think about and use two NGSS SEPs, specifically analyzing and interpreting data and constructing explanations and designing solutions. Archived data provided information for the background of the study. The intervention class experienced introductions to the content, procedures, and focus NGSS SEPs for online laboratories. The researcher studied qualitative and quantitative data and determined there was an increase in student completion of the laboratories in general as well as identifiable impacts on student questions and thoughts about and use of the NGSS SEPs of focus. Data included pre- and post-course surveys, student laboratory questions, laboratory completion rates, laboratory scores, and laboratory answer analyses.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PICTURES

LIST OF ABBREVIATIONS

AAAS	American Association for the Advancement of Science
CARP	Contrast, Alignment, Repetition, and Proximity
iNACOL	International Association for K-12 Online Learning
NRC	National Research Council
NGSS	Next Generation Science Standards
NSTA	National Science Teachers Association
SEPs	Science and Engineering Practices

CHAPTER ONE: INTRODUCTION

This chapter gives an overview of the research project, a statement of the problem, purpose of the study, the context, and a theoretical framework. This information justifies the necessity of the research while presenting key ideas considered when formulating the study.

Overview

In our contemporary technology-based world, online educational opportunities have become important in the education of all subjects including science. According to the United States Department of Education statistics, the number of students enrolled at online K-12 schools in the United States during the 2009-2010 school year was estimated to be 1,816,400 with 74% studying at the high school level (Queen & Lewis, 2011). Furthermore, Gemin, Pape, Vashaw, and Watson (2015) share data for the 2014-2015 school year showing that there were a projected 4.5 million supplemental course enrollments for K-12 students online; their data more specifically estimates that 14.1% of online courses were in science. Additionally, 49% of the principals surveyed by Project Tomorrow (2015) state that they were specifically using online science courses.

There are many reasons for utilizing online instruction. Project Tomorrow (2015) survey data show that principals are turning to virtual instruction to maintain student interest, provide remediation, increase access for homebound students, solve scheduling problems, deliver higher level coursework, and offer subject matter when qualified teachers are limited. Picciano and Seaman (2010) found that the largest percentages of high school administrators believe online and blended learning help enhance course offerings (79%), provide for credit recovery (73%), deliver AP courses (61%), and allow schools to meet the needs of learners (60%). Along with school interest in digital learning, students appreciate social and collaborative learning that is untethered with minimal limitations, as well as “learning that is digitally rich in context and relevancy” (Project Tomorrow, 2015, p. 15).

As online courses are being used to meet the needs of schools and students, it is important to make sure they are highly effective. The National Science Teachers Association (NSTA, 2016a) has a position statement backing the implementation of a variety of online science learning opportunities for K-12 students. They state that online learning must help better the work of science teachers and students (NSTA, 2016a). However, the organization goes on to recommend that such experiences be carefully planned. Educators must ensure the pedagogical integrity for science courses be maintained with digital instruction (Miller, 2008). According to the NSTA (2016a), online instruction must be based on both research about learning and best instructional environments. Some important items highlighted by the NSTA (2016a) include focusing on course design, student interest, relevance, standards, and interactions.

The most current national science standards are the *Next Generation Science Standards* (NGSS), which are based on the previous *National Science Education Standards* (NGSS, 2013e). These standards call for teachers to focus on disciplinary core ideas, crosscutting concepts, and science and engineering practices (SEPs) in science courses (NGSS, 2013e). There are eight SEPs addressed in the NGSS (2013e). These include:

1. Asking questions and defining problems
2. Developing or using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information (NGSS, 2013e)

The SEPs are skills that are important for students to demonstrate in science classes and are not just teaching practices (Pruitt, 2014). These practices facilitate student understanding of knowledge formation and connect activities to content (NGSS, 2013b).

In addition to the NGSS there are resources establishing high quality design for online instruction, including the *National Standards for Quality Online Courses* (iNACOL, 2011a) and Standards from the *Quality Matters K-12 Secondary Rubric, Fourth Edition* (Maryland Online, 2016). Other resources, such as the *National Standards for Quality Online Teaching* (iNACOL, 2011b), focus on online instructional practices. Clear course expectations, focusing on key ideas, incorporating active and relevant learning activities, and designing supportive resources through links and media are some relevant insights offered by these standards.

With distance education, it is also important to consider transactional distance. Moore (1991) describes transactional distance as differences in understandings due to geographic separation. Moore (1991) further suggests that distance education courses can overcome this obstacle with course structure and dialogue. Interactions, such as student-

student, student-content, student-teacher, teacher-content, teacher-teacher, content-content, learner-group, and teacher-group, can allow for course dialogue (Anderson, 2008).

When considering online science instruction specifically, the NSTA (2016a) recommends that online education be structured to facilitate strong instruction in science. Some ways it suggests to do this is through careful design, clear goals, active and authentic experiences, and frequent interaction. Furthermore, the National Research Council (NRC, 2012) asserts that the development and use of SEPs are important in describing phenomena and creating solutions.

Jeschofnig and Jeschofnig (2011) stress the importance of laboratories in online courses. Kennepohl (2013) discusses that considering laboratories in the online environment can be hard, but the goal of such laboratories should be to help students understand how to utilize knowledge. Crippen, Archambault, and Kern (2013) share some options for laboratory activities in the online environment such as:

- virtual laboratories calling for student set up and work with virtual equipment
- hands-on laboratories requiring students to set up and complete laboratories at home
- simulation laboratories using virtual activities without student setup
- remote laboratories allowing students to use laboratory equipment at another location

Studies have compared online and face-to-face laboratories (Brinson, 2015; Gilman, 2006; Johnson, 2002; Klahr, Triona, & Williams, 2007; Lin, Liang, & Tsai, 2012; Lunsford, 2008; Nickerson, Corter, Esche, & Chassapis, 2007; Pyatt & Sims, 2011;

Reeves & Kimbrough, 2004; Shegog, Lazarus, Murray, Diamond, Sessions, & Zsifmond, 2012; Stucky-Mickell & Stuckey-Danner, 2007; Swan & O'Donnell, 2009) and found many positive aspects of such activities. Adding videos is one recommendation that exists for improving online laboratories (Clary & Wandersee, 2010). Another is providing scaffolding (Scalise, Timms, Moorjani, Clark, Holtermann, & Irvin, 2011). Online introductions to laboratories may help with these recommendations. They can be one way to enhance laboratory courses online to better achieve the highest quality science instruction.

Statement of the Problem

Online courses are becoming an important way to provide more course offerings and flexibility to meet the needs of students and schools (Picciano & Seaman, 2010; Project Tomorrow, 2015). Therefore, it is critical to ensure that teachers teach these courses with the most effective instructional strategies to meet current standards (NSTA, 2016b; Miller, 2008). With the NGSS (2013e), one important requirement is using the eight SEPs.

Due to the newness of the standards, there is a need to create quality materials and experiences that are based on the NGSS SEPs (NSTA, 2016b; Pruitt, 2014). In online classes, laboratories can provide a way for students to use the NGSS SEPs. Pruitt (2014) says that even though the standards were created based on research, there is much to discover about how to implement the NGSS. Online laboratory introductions may be crafted to help familiarize students with key content, assignment procedures, and NGSS SEPs. They can be one way to help students better formulate their questions about laboratories, complete laboratories, and show more thinking about and use of the NGSS

SEPs. In an online class setting students can choose to skip the laboratory activities or struggle to adequately analyze and interpret data and construct explanations and design solutions.

The introductions designed for this study addressed this by explaining key laboratory content, procedures, and two NGSS SEPs (analyzing and interpreting data and constructing explanations and designing solutions) (Appendix A). I developed the introductions using h5p, which is an online tool to make interactive content (H5P, 2017). As I constructed each I considered good multimedia design (Clark & Mayer, 2011; Lewis, 2000; Mayer, 2001), copyright (U.S. Copyright Office, 2016), and accessibility to meet the needs of various learners (ADA, n.d.; U.S. Department of Justice, 2009; W3C, 2018). I posited that this might be beneficial to student learning by helping students better interact with the content and the teacher, complete laboratories, and think about and use the focus NGSS SEPs. This could not only help students in the online classes I teach, but also facilitate the creation of resources to benefit other students.

Purpose of the Study

The purpose of the study was to help students better interact with the content and the instructor by completing laboratory introductions. The goal of such interactions was to allow students to ask questions about laboratories, complete laboratories, and have thoughts about and use of two NGSS SEPs (analyzing and interpreting data and constructing explanations and designing solutions). I created laboratory introductions related to the key ideas, procedures, and the two focus NGSS SEPs. After students interacted with the introductions, they had the opportunity to ask questions about the laboratories. I responded to and analyzed their questions. Then, I monitored how these introductions impacted student laboratory completion rates, student questions about laboratories, and thoughts about and use of the two NGSS SEPs (analyzing and interpreting data and constructing explanations and designing solutions).

This study answered several research questions. Do introductions before online forensic science laboratories focused on key content, procedures, and two NGSS SEPs (analyzing and interpreting data and constructing explanations and designing solutions) promote (1) student interaction with the course instructor by asking questions before completing the laboratories?, (2) student completion of those laboratories?, (3) student thinking about the NGSS SEPs?, and (4) student use of those NGSS SEPs in laboratory responses?

There was significance but also limitations to the study. It was significant because it provided introductions for students to interact with the content and the teacher. This dynamic offered students the opportunity to articulate their questions about the laboratories and caused students to be more likely to complete some laboratories and think about and use the two NGSS SEPs of focus. It is important for instructors to implement strategies that help students complete laboratories and think about and use the SEPs of the NGSS. With the recent creation of the NGSS, there is limited research regarding how to best design instruction based on these standards (Pruitt, 2014). However, the study was limited because the number of participants was small and required consent, restricting generalizability. There were also limitations due to a lack of tracking to determine how much students interacted with the interventions and a previously published survey and rubric to evaluate student reactions to the intervention.

Context

My teaching and educational experiences provided me with a strong background for the study. My background includes teaching math and science at a charter school for nearly three years, science at a traditional face-to-face public school for five years, and science at an online state virtual school for over 10 years. I hold a Bachelor of Science in Biology, a Master of Science in Environmental Science, a secondary science teaching certificate, and an Education Specialist Degree in Education. I have also completed coursework towards an Ed.D. in Curriculum and Instruction. Combined, this experience and education has provided a firm foundation in science education and prepared me to complete this study.

I have enjoyed teaching science and learning about science for many years and have drawn on both educational and work experiences to improve my practice. After obtaining a MS degree in Environmental Science, I decided to become a secondary instructor and accepted a position teaching at a charter school. During this time, I worked on developing my practice and obtained teaching credentials. Once obtaining more experience and knowledge of science teaching practices, I completed an EdS in Education while teaching Biology and Physical Science classes at a traditional public school. There, I focused on developing common laboratories and a laboratory report grading rubric that increased effective student use of laboratory reporting components to improve student achievement of the goals related to the *National Science Education Standards* (NRC, 1996), *Project 2061: Science for All Americans* (American Association for the Advancement of Science (AAAS, 1990), and *Benchmarks of Science Literacy* (AAAS, 2009).

After teaching face-to-face science classes, I obtained employment as a science instructor in an online environment. Initially, I worked to promote inquiry in science labs and achieve the goals of the *National Science Education Standards* (NRC, 1996) in my online courses. I also became proficient in the *National Standards for Quality Online Teaching* by iNACOL (2011b), the *National Standards for Quality Online Courses* (iNACOL, 2011a), and the *Quality Matters K-12 Secondary Rubric* (Maryland Online, 2016) through cognate coursework during my Ed.D. program. I obtained both a Graduate Certificate in K-12 Online Teaching and a teaching endorsement in that area. These opportunities helped me to identify and implement best online teaching practices in my online science courses.

While enrolled in the Ed.D. program, the NGSS (2013e) became the national science standards. These standards provided me with new ideas about science proficiency for K-12 students today. They describe science as both knowledge and an endeavor that uses evidence, models, and theories to continually build knowledge. It consists of three dimensions: disciplinary core ideas, crosscutting concepts, and SEPs. Disciplinary ideas are key science concepts that are important to science understanding. Crosscutting concepts are science ideas that are important across all areas of science. SEPs are used by scientists and engineers to apply knowledge.

With the development of the NGSS (2013e), I became interested in the use of SEPs to help students better achieve the skills necessary for maximum learning during online science classes. As students struggle to use these practices or skip laboratories all together during the online laboratories I teach, my thoughts moved towards introductory interventions for these practices. This study tested the effectiveness of the introductions to increase student interactions with content and the teacher to help laboratory completion rates and student thoughts about and use of the NGSS SEPs.

I approached this study as a teacher with about 19 years of experience instructing a variety of face-to-face and online science courses. There are several different formats available to deliver course content online. According to Gemin et al. (2015), online learning occurs with teacher instruction over the Internet. Students and instructors are not present in the same location, but instead rely on the web and educational software for learning to occur. This can be achieved through real time, synchronous instruction or by asynchronous interactions. Such courses can be delivered to students inside or away from brick and mortar school locations. For the purpose of this study, I considered an online science course as a web-based, asynchronous class delivered via Blackboard.

Theoretical Framework

In this study, I drew on two theories: the NRC's (2012) *Framework for K-12 Science Education* and transactional distance in online learning and the importance of interactions, to frame the inquiry into the research questions. These two concepts are important because the framework provides the key science ideas students should know and transactional distance can be a hinderance to achieving the goals of the framework in the online environment. By working to reduce transactional distance and improve online science instruction, online science courses could become stronger and more helpful to students.

Framework for Science Education

The NRC framework sees science and engineering as important in providing solutions to alleviate problems in today's world (NRC, 2012). In this view, science is needed by all students for success in life and also offers a means to keep the United States competitive. The framework centers on key SEPs, crosscutting concepts, and disciplinary core ideas. It offers a vision of science education that incorporates these parts to deepen student understanding. Its goal is to provide a way to allow students to become:

- critical consumers of science information
- lifelong science learners
- people with an appreciation for science

Since the framework relates the SEPs to key ideas and crosscutting concepts, it provides a foundation for the present study. This study sought to add introductory information about two SEPs (analyzing and interpreting data and constructing explanations and designing solutions) before laboratories. This design is meant to help students think about and utilize SEPs better during online course laboratories. Learning about the SEPs may help students think about and use the NGSS SEPs.

Transactional Distance

Another idea at the center of my research is transactional distance. Distance education creates transactional distance. According to Moore (1991), transactional distance can lead to variations in understanding and perceptions caused by differences in geography. Moore and Kearsley (2005) describe such distance as a teaching situation that is not certain but changing with circumstances. Transactional distance creates a large enough distance between teachers and students that it must be adjusted for. It can be compensated for with using distinct educational behaviors in order to meet instructional goals (Moore, 1991).

Two ways to overcome transactional distance are with dialogue and course design (Moore, 1991). Dialogue is “the interplay of words and actions and any other interactions between teacher and learner when one gives instruction and the other responds” (Moore & Kearsley, 2005, p. 224). Course structure includes the various components of course design such as “learning objectives, content themes, information presentations, case studies, pictorial and other illustrations, exercises, projects, and tests” (Moore & Kearsley, 2005, p. 226). With increasing levels of transactional distance, learners need to use more autonomy (Moore, 1991). Therefore, designers can carefully create courses for quality (Moore & Kearsley, 2005).

Interactions can be instrumental in distance education. Some interactions include student-student, student-content, student-teacher, teacher-content, teacher-teacher, content-content, learner-group, and teacher-group (Anderson, 2008). In this study, I focused on three types of interactions: student-content, student-teacher, and teacher-content.

First, learner-content interactions happen as a result of teachers organizing content (Moore & Kearlsey, 2005). Learners have to make their own knowledge through adding new information to previous cognition with teachers facilitating this process (Moore & Kearsley, 2005). Anderson (2008) adds that some content can be interactive to adjust to student needs.

Next, learner-instructor interactions occur as teachers spark student interest, facilitate application, evaluate, and support student learning (Moore & Kearlsey, 2005). It provides opportunities for the teacher to respond most appropriately to individual learners (Moore & Kearsley, 2005). Moore (1989) adds that this type of learning is highly wanted by students. Anderson (2008) points out that such interactions can be asynchronous or synchronous.

Finally, Anderson (2008) shares that teachers can interact with content. This happens as teachers construct course content, as well as review courses and adjust current courses as needed (Anderson, 2008).

By adding introductory activities before laboratory assignments, students have the opportunity to interact with SEPs and the instructor as they prepare to learn science knowledge and skills during the laboratory assignments. This may help ensure that the online science course delivers the highest quality instruction based on the NRC (2012) framework with the least amount of restrictions due to increased transactional distance. The teacher can also interact with students and content through the introductions to better meet the needs of all learners.

Chapter Summary

This chapter provided an overview of the research project, a statement of the problem, purpose of the study, context, and theoretical framework. This information lays the foundation for the study, the focus of the literature review, research methodology, data analysis, and conclusions. The next chapter is a discussion of the literature related to this topic.

CHAPTER TWO: LITERATURE REVIEW

This chapter provides a review of literature related to the study. The goal of the research was to study how adding introductions before laboratories in online courses helped improve student interactions with laboratory content and the teacher, laboratory completion, laboratory report scores, and student thoughts about and use of two NGSS SEPs. The SEPs of focus for the study were analyzing and interpreting data and constructing explanations and designing conclusions. Topics for the literature review include online course design and teaching standards, science content standards, introduction features and best practices, and online science laboratories. Being aware of current science content standards helped focus my research on important science practices. Knowing about the online course design and teaching standards, the best introduction design features, and information about online laboratories allowed me to carefully create laboratory introductions and maximize their potential for effectiveness.

Online Course Design and Teaching Standards

There are distinct factors to consider with online learning. With students and teachers separated from one another by geography, there can be variations in understanding and perceptions, or transactional distance (Moore, 1991). Online educators use carefully designed courses and dialogue to minimize this transactional distance (Moore, 1991). Research suggests that using intentional course design and helpful dialogue between the teacher and the learners can improve student learning (Moore & Kearsley, 2005).

Data Driven Online Learning

One way to carefully design online courses is by consulting quality assurance frameworks that include rubrics for developing quality online courses. Course design rubrics are usually based on a set of standards focused on the content, design, technology, assessment, and overall management of online courses (iNACOL, 2011a). Such rubrics help course instructors design effective courses. For example, a report by the Florida International University Online (2016) showed how Quality Matters Certification helped lead its courses towards more student interactions, higher course access minutes, and improved grades. I have highlighted two sets of online course design standards in this literature review as these are the focus course design rubrics at the study school. One is the *National Standards for Quality in Online Courses Version 2* from iNACOL (2011a). The other is the *Quality Matters K-12 Secondary Rubric, Fourth Edition* (Maryland Online, 2016).

In addition to course design rubrics, there are also rubrics available to help teachers utilize the best practices in the online teaching environment. For this study, I consulted the iNACOL (2011b) *National Standards for Quality Online Teaching Version 2*.

iNACOL Online Course Design Standards

iNACOL (2011a) based their initial online course design standards from the Southern Regional Education Board (SREB) standards. iNACOL *National Standards for Quality in Online Courses Version 2* help course designers create online courses with evidence-based research. The standards address online course design for content, instructional design, student assessment, technology, course evaluation and support

(Figure 1). Content describes the need for effective academic standards and assessment, clear course overviews and introductions, legal and acceptable use policies, and instructor resources. Instructional design should consider audience needs, careful course design with clear units and lessons, instructional activities that meet a variety of learning needs through engaging activities, high levels of communication and interactions, and enriching materials. Student assessment ought to include effective evaluation strategies and frequent varied feedback with the necessary assessment materials. Technology should allow for teachers to add content and use it with multiple schedules, clear navigation and media, the ability to meet technical requirements, and interoperability. It must also enhance course accessibility and security. Finally, courses should be analyzed for effectiveness, be updated frequently, and offer support (Figure 1).

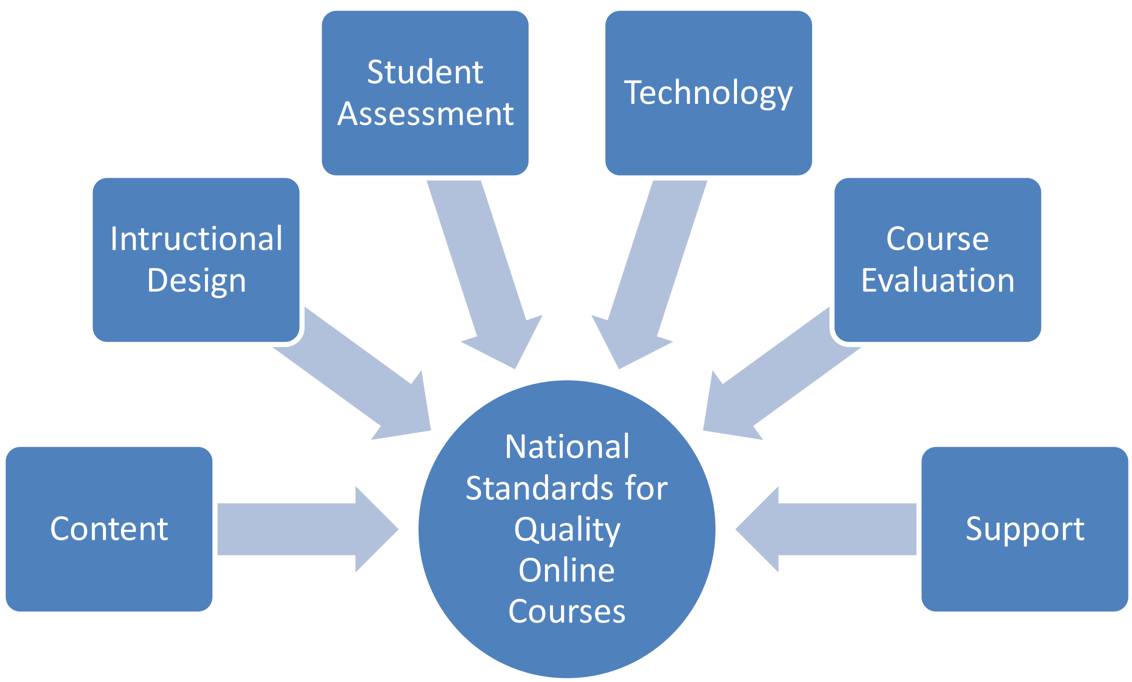


Figure 1. Components of iNACOL's National Standards for Quality in Online Courses Version 2

Quality Matters K-12 Standards

The *Quality Matters K-12 Secondary Rubric, Fourth Edition* is from Maryland Online (2016). The original standards release was in 2010 with improvements added due to the input of online teachers, instructional designers, and standards from online education organizations. Researchers also evaluated them in light of current literature. There are eight areas listed in the rubric: course overview and introduction, learning objectives (competencies), assessment and measurement, instructional materials, course activities and learner interaction, course technology, learner support, and accessibility and usability (Maryland Online, 2016) (Figure 2). The course overview should make it easy to get started on the course with the purpose and structure, necessary technical skills, netiquette, standards, instructor information, and required knowledge identified. Learning objectives ought to be clearly defined, measurable, and aligned to students, standards, and activities. Multiple assessments must align with the course, have clear evaluation standards, allow for self-reflection, and provide for clear course expectations. Instructional materials should align to learning, be clear, appropriate, have depth, be cited correctly, and be free of bias and advertisements. Course activities ought to be aligned to objectives, support learning, be clear, and explain necessary interactions. Course technology should match learning goals, promote active learning, be easy to obtain, be current, and allow for privacy. Learner support needs to be available for both institutional and technical support. Accessibility should include easy navigation, information about accessibility, alternative formats, readability, and be easy to use.

Figure 2. Components of the Quality Matters K-12 Secondary Rubric, Fourth Edition

iNACOL Online Teaching Standards

Another guide for online courses is online teaching rubrics. iNACOL's *National Standards for Quality Online Teaching Version 2* offers standards to lead organizations towards good online teaching (iNACOL, 2011b). This version, which is a modification of the standards from the SREB, has information to describe both what online teachers need to know and do (iNACOL, 2011b). The main items to consider from the rubric are: online instruction, technologies, teaching strategies, promotion of student success, legal and ethical issues, student needs, assessments, standards-based learning goals, assessment data, professional behavior, and instructional design (iNACOL, 2011b) (Figure 3).

Figure 3. Components of National Standards for Quality Online Teaching Version 2

A summary of these quality teaching standards (iNACOL, 2011b) is as follows. For online instruction, the teacher should be able to identify best practices, prepare students for global learning, understand the different types of online instruction, know the need for continuous professional development, be aware of the content and learners of the course, and recognize how important it is to improve the field. Instructors must be able to use technology tools, emerging technology, and troubleshooting as well as stay current on available technology. Teaching strategies should include instruction based on current applications, developing community, promoting interactions, facilitating online groups, tailoring communications to specific learners, and differentiating instruction. Promotion of student success can occur through communication with clear expectations for a variety of aspects of the course, including course objectives, interactions, student behavior, feedback, student engagement, and course expectations. Teachers must be prepared to address legal and ethical issues including digital citizenship, academic honesty, acceptable use, appropriate use of technology, and privacy. They can also meet the needs of all learners by making appropriate and legally required accommodations, enrich learning, and address student diversity. Assessments should be appropriate, valid, reliable, and secure. Assignments ought to be authentic, based on standards, and continually updated based on feedback. Teachers should be able to utilize data in instructional planning to meet student needs, self-assess, recognize different assessments for ability, evaluate instructional strategies, keep records, use time well, manage classes, assess student readiness, measure their own readiness, and help students form goals for online learning. They also need to participate in professional development and communicate with other adults that are available to help students be successful. A final consideration is knowing what is necessary to participate in elements of course design, such as creating assignments and assessments, using software, and selecting resource links.

Science Standards and the NRC Framework

Effective teachers have a grasp of the content along with knowing how to facilitate student understanding of content through well-designed activities (Bransford, Brown, & Cocking, 2000). This does not change in the online environment. Online teachers should know the content area they are teaching and match up assignments with desired standards-based learning outcomes just like face-to-face teachers (iNACOL, 2011b). In much the same way, online course designers must be able to align learning goals with recognized content standards (iNACOL, 2011a; Maryland Online, 2016). Given this, I began this research project by reviewing the current national science standards. These national science standards were instrumental in determining the most effective course design and teaching practices for the online science course being studied.

<u>NRC Framework</u>

The science content standards have a rich history. In 1996, the NRC (1996) implemented the *National Science Education Standa*rds to guide teachers toward the goals of helping students comprehend the natural world, utilize science to make good choices, participate in discussions about science topics, and become more productive through scientific literacy. The *National Science Education Standards* were individual content standards describing the knowledge students should gain and the skills they should be able to do throughout their K-12 experiences. The content standards consisted of inquiry, physical science, life science, earth and space sciences, science and technology, personal and social perspectives in science, and the history and nature of science (NRC, 1996). The standards came together to facilitate the creation of learning opportunities that provide a foundation for science literacy.

In 2012, the NRC (2012) updated the science content standards in *A Framework for K-12 Science Education*. As states began adopting common standards for both math and English/language arts, the NRC (2012) believed the time was right to develop national science standards as well. The NRC (2012) used some additional sources to guide the development of the new science education standards. These include *Science for All Americans* by the AAAS (1990), the AAAS's (2009) *Benchmarks for Science Literacy,* and the NSTA (n.d.) Anchor's Project.

Science for All Americans stresses the importance of scientific literacy to help people have fulfilled lives, be responsible, and develop thinking skills (AAAS, 1990). It recognizes science is a tool to solve problems and supports an educator focus on scientific literacy. Additionally, *Science for All Americans* provides an explanation of the nature of science, mathematics, and technology (AAAS, 1990). The text shares some of the fundamental knowledge of science, and there is a discussion of the areas of science and human society, the designed world, the mathematical world, and historical perspectives (AAAS, 1990). After identifying key areas, there are highlights of common themes (AAAS, 1990). These themes include systems, models, and constancy versus change.

The *Benchmarks of Science Literacy* was originally written in 1993 with the online version receiving edits in 2009 (AAAS, 2009). While *Science for All Americans* established science goals for people as they reached adulthood, there was still a need to establish resources for educators. The benchmarks provide information about expected student knowledge and skill by grade level (AAAS, 2009). For example, under the scientific world view, there are benchmarks related to the scientific worldview. By the end of 12th grade, students should know that the universe has consistent rules and patterns which can be determined by science, major ideas in science often stay the same with some changes over time, new theories may work better, testing theories is an ongoing process, and value for science grows as researchers better explain and predict phenomena (AAAS, 2009).

Later, the NSTA (n.d.) Anchor's Project set out to create a key set of science education standards for the nation that could be available in print and online. These standards could serve as a guide for science teaching. According to the NSTA (n.d.), they would focus on key skills and knowledge to best utilize limited teaching time. Three reasons for the project were to address the overabundance of science standards being required by states, a lack of clear information about science standards, and concerns about how to properly match up standards with different assessments.

Finally, with the *National Science Education Standards*, texts from the AAAS, and input from the NSTA Anchor's Project, work began to form *A Framework for K-12 Science Education* (NRC, 2012). The framework authors sought to make sure that all high school seniors gain an understanding of the beneficial features of science, have the science knowledge necessary for informed citizenship and consumerism, be able to independently grow in their knowledge of science throughout life and have the background to obtain jobs of their choosing (NRC, 2012). Figure 4 illustrates the influence of previous works used to guide the formation of the framework for the NGSS.

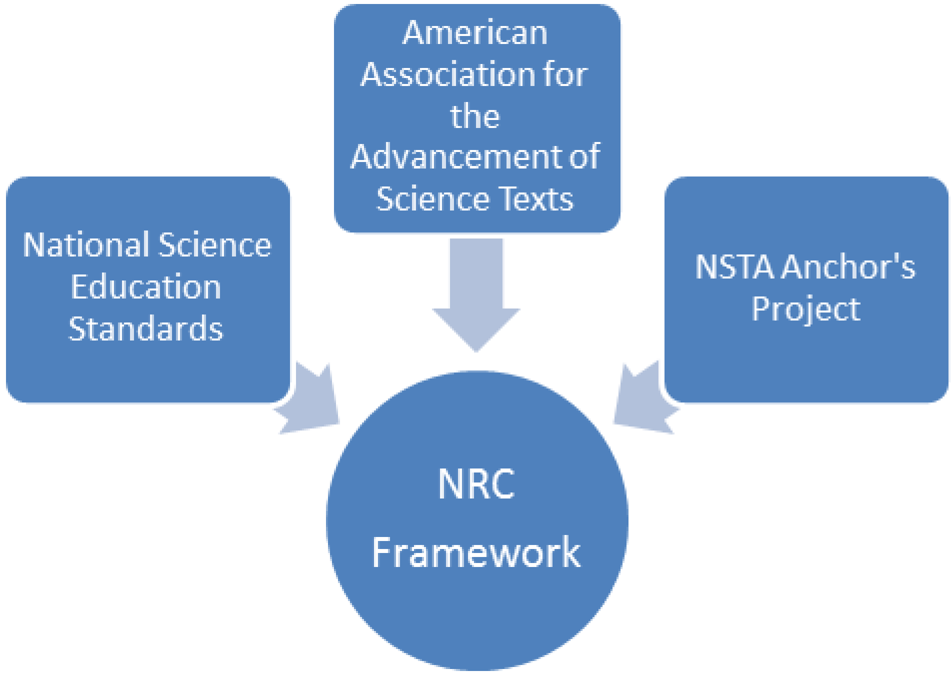


Figure 4. **Components Used in Developing the NRC Framework**

The NRC (2012) framework has three areas of focus: disciplinary core ideas, crosscutting concepts, and science and engineering practices (SEPs) (Figure 5). The SEPs that relate to this study and, therefore, will be discussed in more detail are:

- asking questions (for science) and defining problems (for engineering),
- developing and using models,
- planning and carrying out investigations,
- analyzing and interpreting data,
- using mathematics and computational thinking,
- constructing explanations (for science) and designing solutions (for engineering),
- engaging in argument from evidence, and
- obtaining, evaluating, and communicating information (NRC, 2012).

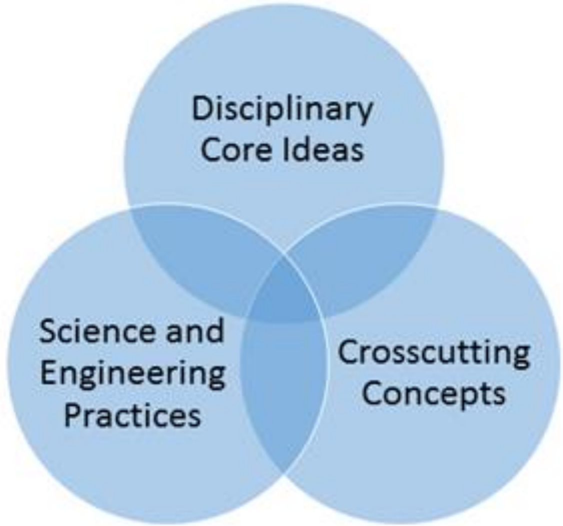


Figure 5. Three Main Areas of the NRC Framework

The crosscutting concepts for all science topics are "patterns; cause and effect: mechanism and explanation; scale, proportion, and quantity; systems and system models; energy and matter: flows, cycles, and conservation; structure and function; and stability and change" (NRC, 2012, p. 3). Core ideas are main topics specific to each content area. An example of a disciplinary core idea related to life science is "from molecules to organisms, structures and processes." (NRC, 2012, p. 3). The authors of the framework expected it to facilitate the creation of new standards as well as guide curriculum, instruction, evaluation, and teacher professional studies (NRC, 2012).

The NRC (2012) explains that this new structure dealt with the latest information in the field and common standards in other subjects. Their goal was to reduce the amount of science information that is key in science learning. The framework was meant to focus student learning and skill development by constructing and revisiting learning over time (NRC, 2012). They also envisioned reducing core ideas "to give time for students to engage in scientific investigations and argumentation and to achieve depth of understanding of the core ideas presented." (NRC, 2012, p. 11). Finally, the framework was a way to show that both "knowledge and practice" can be used together during K-12 science instruction (NRC, 2012, p. 11).

Next Generation Science Standards (NGSS)

After the framework structure came together, Achieve, Inc. helped guide the development of the NGSS based on the framework (NRC, 2012). In April of 2013, the NSTA (2014) welcomed the standards as a transformative agent in science education. Forty-one writers, including teachers and other professionals from key fields, helped with the development of the standards (NSTA, 2014). The effort was led by 26 states (NRC, 2012).

There was a need for these standards (NGSS, 2013e). It had been 15 years since the *National Science Education Standards* were released and many changes in science had taken place during that time. These standards provide new information to better guide science education. They are also a way to encourage more students to enter science, technology, engineering, and mathematics (STEM) fields by focusing on science and engineering practices. Finally, the new standards better prepare learners to think critically and use inquiry both in their college experiences and careers.

Three Areas of Learning

The new science standards consist of three areas: core content ideas, SEPs, and crosscutting concepts from the NRC framework (NGSS, 2013e). The standards promote the incorporation of more than one core concept over an academic year, as well as building on learning over time. Their emphasis on a lesser number of ideas is meant to allow for greater understanding with less focus on facts while also concentrating on engineering and technology and performance expectations. Furthermore, the standards allow for the integration of *Common Core State Standards* related to math and English/language arts. Figure 6 shows how the NGSS are laid out.

<table>
<tr><td colspan="3">Performance Expectations</td></tr>
<tr><td>Science and Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td colspan="3">Connections to Disciplinary Core Ideas in the Grade</td></tr>
<tr><td colspan="3">Articulation of Disciplinary Core Ideas across Grades</td></tr>
<tr><td colspan="3">Common Core State Standards Connections</td></tr>
</table>

Figure 6. Components of the NGSS

The NGSS include performance, foundations, and coherence (NGSS, 2013d). In addition to the previous practice of expressing what students ought to learn, these new standards go further by adding measurable performances that can be achieved with the knowledge. Students should be able to show mastery of all major performance expectations, however, there is no specific curriculum for these goals. Furthermore, NGSS focus on what students should be able to accomplish after successful course completion.

There are several items supporting performance expectations. Disciplinary core ideas are key ideas from the various science topics that students should learn about during their K-12 instruction (NGSS, 2013d). These also have sub-ideas for specific grades. There are also SEPs (NGSS, 2013d). Participating in science practices allows students to see how science knowledge is created while engineering practices help them to understand how engineers use this knowledge (NRC 2012). Finally, there are crosscutting concepts that are important across science (NRC, 2012).

The NGSS SEPs require student engagement and interaction with content. Fredricks, Blumenfeld, and Harris (2004) identify three components of student engagement. The first component of engagement is behavioral, which is shown by student participation in activities. Next, there is emotional engagement, or students having positive thoughts towards learning activities. Lastly, cognitive engagement is demonstrated when students exhibit the work to make sure they comprehend a concept. Engagement with SEPs assists students in seeing how knowledge in science is formed, enhancing positive awareness of scientific activities, grasping how professionals work, and creating meaningful links to ideas (NGSS, 2013b).

The first SEP is "asking questions and defining problems" (NGSS, 2013b, p. 4). The NGSS (2013b) discuss this practice in detail. Questions in science can develop through inquisitiveness; can be driven by models, theories, or data; or form as a result of necessity. An initial question can even lead to new questions to explore. Question quality is a key factor in question development.

"Developing or using models" is the second SEP (NGSS, 2013b, p. 6). The NGSS (2013b) share important information about models. Models can include a variety of different reproductions, such as simulations and physical creations. While models can help people visualize certain concepts, they can also be limiting. This is because models often cannot express the complexity of what happens in the world. However, models can be helpful when asking questions, explaining information, using data for predictions, and delivering ideas. Models can help with the conceptualization of thoughts. Furthermore, they remain flexible, or can be modified as facts change.

Students can articulate how they will study a concept by using the third SEP, "planning and carrying out investigations" (NGSS, 2013b, p. 7). According to the NGSS (2013b), people participate in this practice as they study both science and engineering investigations (NGSS, 2013b). Engineering investigations relate to how to make a product better or analyze different solutions for maximum effectiveness. To plan and carry out an investigation, one must always share his/her goal, predictions, and activities. There should be improvement in one's ability to plan and complete scientific studies over time.

Along with completing investigations, students must participate in "analyzing and interpreting data" (NGSS, 2013b, p. 9). The NGSS (2013b) discuss student analysis and interpretation of data. One's ability to show data should get better over time. People should be able to show patterns, utilize math to depict variable relationships, and consider error. Data can also enhance conclusions.

"Using mathematics and computational thinking" is a key SEP (NGSS, 2013b, p.10). The NGSS (2013b) share why these are so important. Math can show relationships between variables and also help with predictions. Logical thinking and various types of math can be applied to science. Furthermore, computers can assist in calculations, estimating additional data points and studying data. Competency in using tools in conjunction with a computer for data collection and analysis is a must. One should also participate in the search for information, such as the use of sequenced algorithms, and simulations.

Once data collection and analysis are complete, students must be competent in "constructing explanations and designing solutions" (NGSS,2013b, p. 11). The NGSS

(2013b) elucidate that explanations and solutions are critical in science. Information can help with the creation of understanding. In science, assertions relate to variables. Claims are usually formulated after asking a question and collecting data. In engineering, problems are the focus. Problems are expressed to test and enhance possible solutions over time.

After students have their explanations and solutions, they should be "engaging in argument from evidence" (NGSS, 2013b, p. 13). The NGSS (2013b) discuss that it is through reflecting and evaluating arguments and evidence that explanations of science or the best solutions to problems can form. In order to effectively come up with explanations and solve problems, one must be able to actively listen and consider multiple thoughts.

The last area of SEPs is "obtaining, evaluating, and communicating information" (NGSS, 2013b, p. 15). The NGSS (2013b) articulate that reading, explaining, and creating scientific writing is a key process. People must be able to digest and generate thoughts about scientific and engineering writing. They must consider more than one source of information to express how valid a claim is. They should also be able to show information in more than one way, such as through graphing, making tables, writing, equations, etc.

Crosscutting concepts are select concepts that relate to more than one performance expectation (NGSS, 2013d). They are not designed to restrict instruction. The seven crosscutting concepts are patterns; cause and effect: mechanism and explanation; scale, proportion, and quantity; systems and system models; energy and matter; structure and function; and stability and change (NGSS, 2013d). The NGSS

(2013d) share some information about these concepts. They are designed to facilitate the understanding of core ideas and science and engineering practices, increase familiarity with contexts by revisiting concepts, and provide a shared language. Achievement of these should be determined along with core ideas and practices. However, the performance expectations may not concentrate on all the possible crosscutting concepts (NGSS, 2013a). It is also important to remember that every student should learn about crosscutting concepts and not just higher-level learners.

Connections help identify links to other instructional aspects (NGSS, 2013e). They include various science topics, grade levels, and *Common Core State Standards*.

A summary of the NGSS can be described for high school physical science to illustrate the general design of these standards (NGSS, 2013c). There are five main topics in the NGSS for physical science, including structure and properties of matter, chemical reactions, forces and interactions, energy and waves, and electromagnetic radiation (NGSS, 2013c). The standards incorporate all eight SEPs, four disciplinary core ideas, and six crosscutting concepts. There are also connections to the nature of science along with connections to engineering, technology, and the application of science. Links to other disciplinary core ideas at the grade level, across other grade levels, and in relation to the *Common Core State Standards* are present.

NGSS in Action

Without a clear vision of how the NGSS SEPs should be present in instruction, it will take time and effort to implement them in the classroom (NSTA, 2014; Pasley, Trygstad, & Banilower, 2016). The introductions for the study presented the key content ideas, directions on how to complete enriching online laboratory experiences, and information about two focus NGSS SEPs, analyzing and interpreting data and constructing explanations and designing solutions. Looking at ways to enhance student understanding of key ideas, activities, and SEPs aligns well with the goals of current national science standards and has the potential to add one strategy to help with implementation of the NGSS (2013d) in online science courses. It is the hope that with these introductions students might be more likely to complete laboratory assignments with high quality work while thinking about and using the focus SEPs.

Course Design and Teaching Practices

After looking at the current science standards, I explored some standards for online course design and teaching. The following section describes some key factors I considered about online course design and best practices in online instruction. There are links between various online course design standards, teaching practices, and the laboratory introductions. Such links show what I considered as I designed the laboratory introductions and how they support best practices for online science course design and teaching.

Clear Expectations

Course expectations are important in online course design and teaching. Maryland Online (2016) standards state that learning objectives for activities should be clear as well as address how instructional materials are being used. iNACOL's (2011b) teaching standards advocate that teachers be able to clearly define objectives, concepts, and learning goals.

There is research supporting such clarity in online course design and teaching. In a study of undergraduate and graduate students in South Dakota, Reisetter and Boris

(2009) found that 95% of students studied “believed that the structure and coherence of the course was very or somewhat important, and that expectations had to be explicit.” (p. 166). Additionally, DiPietro, Ferdig, Black, and Preston (2010) learned through a study of Michigan Virtual School teachers that one characteristic of its best online instructors was that they provided students organized content to use. Cohen and Ellis (2004, p. 166) conducted a study showing that one quality indicator of online courses was “expectations clearly articulated”. One of Barbour’s (2007) seven guidelines for effective web-based content based on interviews with course developers and teachers is making sure that expectations and directions are clear. Finally, Thomson (2010) states that courses should be organized with well-articulated expectations and instructions.

The laboratory introduction design in this study can help add to the clarity of online science laboratories. They provide a place to elaborate on laboratory expectations for content knowledge, procedures, and the focus SEPs.

Focusing on Key Ideas

Along with clear expectations, rigorous coursework should provide instruction focusing on key ideas. According to the iNACOL course design standards, topics must be explored in enough depth and breadth. Maryland Online (2016) supports this suggestion by stating that items used for instruction should have the proper level of topic coverage with current information and the necessary depth.

The need for focusing on key ideas goes beyond online research. Bloom, Englehart, Furst, Hill, and Krathwohl (1956) discuss difficulties when designing curriculum and instruction about choosing objectives, learning experiences, and assessments. They recognize the need to learn some factual knowledge because observations and experiments help explain scientific information (Bloom et al., 1956). They assert that knowledge provides the foundation for learning how to complete the scientific method. This holds true even if the knowledge learned is later proven incorrect.

Once recognizing a need for factual knowledge, it is important to carefully consider what will be taught and how it will be taught. Bransford, Brown, and Cocking (2000) state that students must have a deep understanding of facts and ideas in context to organize information for later access and application. Therefore, instructors ought to concentrate on a limited number of facts and a multitude of examples. According to AAAS (1990), when thinking about learning, it is important for teachers to remember that research on cognition shows that even with good teaching many learners do not comprehend all teachers think they do. Therefore, it is vital to remember that effective science instructors de-emphasize memorization and make understanding the key to instructing science (AAAS, 1990).

Wiggins and McTighe (2005) add to this by recommending a focus on big ideas and the backward design process to reach more effective levels of learning. Backward design starts with determining desired results, or what a teacher expects students to learn. This is done by considering standards, curriculum, and a variety of student factors. Next, teachers figure out what will be acceptable proof of learning. Finally, educators can plan learning experiences with a focus on the knowledge and skills needed. Knowledge should be focused on big ideas, or high priority items, instead of encompassing many minute facts about a topic.

According to the AAAS (1990), instructors should allow students time for investigating science concepts to study questions, read, make arguments, explore ideas, and construct different ideas. Leonard, Fowler, Mason, Ridenour, and Stone (1991) research on teachers instructing introductory high school biology courses supports this. Teachers expressed the need to reduce the amount of content delivered to students at that level. Instead of requiring students to learn large vocabulary lists and volumes of unrelated facts, "some content expectation needs to be traded off for high quality instruction in science process skill development, for the development of general principles and themes, and for developing a relationship to the real world" (Leonard et al., 1991, p. 402).

The NGSS (2013e) reinforce the need to limit factual knowledge by focusing on pivotal concepts through core ideas. For example, when writing about the standards and biology, Bybee (2012) says that despite the multitude of ideas in biology a limited amount of key concepts provides the foundation for science learning. With a limited number of disciplinary core ideas, teachers can begin to focus on the most important concepts students should understand about a topic (NRC, 2015).

Krajcik, Codere, Dahsah, Bayer, and Mun (2014) point out that the three dimensions of *A Framework for K-12 Science Education* (NRC, 2012) and the NGSS (2013e), which are SEPs, disciplinary core ideas, and crosscutting concepts, facilitate a deeper comprehension of topics by connecting ideas. The NGSS shift teacher focus from discrete facts to core ideas and crosscutting concepts to develop explanations and come up with solutions to problems. Through SEPs, disciplinary core ideas, and crosscutting concepts, learners have a network of interrelated ideas to explain happenings, provide solutions, and make choices (Krajcik et al, 2014).

Another influence affecting the acquisition of knowledge is the fact that students must construct meaning for themselves (AAAS, 1990). If students are not able to consider new information in light of previous understanding, they may not be able to understand a concept well and apply that concept away from school (Bransford, Brown, & Cocking, 2000). Students enter classes with many thoughts and skills related to nature (Duschl, 2003). Minstrell (1989) supports this saying that each student comes to class with different knowledge, therefore, teachers must realize this and work to show differences between previous and present knowledge or bring the two knowledges together. Therefore, instructors have to address the previous conceptual understandings of students (Bransford, Brown, & Cocking, 2000).

Focusing on key ideas supports both best online course design and online science teaching practices. The laboratory introduction design emphasizes key content for the laboratory, thus making it clear to students what the key concepts are and providing them with information as they try to understand these concepts.

<u>Activities</u>

Activity design is important in online education. Online course activities must be well designed to help students be active learners and higher-level thinkers (iNACOL, 2011a). The Standards from the *Quality Matters K-12 Secondary Rubric, Fourth Edition* provide recommendations for learner interaction and engagement, specifically stating that assignments must be designed to allow for active learning (Maryland Online, 2016).

It is also critical for students to have opportunities to understand their learning through multiple contexts, activities incorporating transfer, and metacognition (Bransford, Brown, & Cocking, 2000). Multiple contexts allow students to see new information in different ways and be better able to represent the knowledge in their minds. Activities focusing on transfer allow students to consider their original ideas about a topic and work to new understandings that they can apply outside of school. It is also important to develop the metacognitive abilities of students so that they can think about their learning by saying what they learned and reflecting on their understanding.

According to the AAAS (1990), if students are only able to practice using novel problems, they can only solve such problems. They state that, “students cannot learn to think critically, analyze information, communicate scientific ideas, make logical arguments, work as part of a team, and acquire other desirable skills” until they have the opportunity to do these things many times (AAAS, 1990, p. 199). Krajcik et al. (2014) support this view suggesting that both content and practice are important components of science instruction. This is further reinforced in the NGSS (2013e) by the inclusion of performance expectations. The NRC (2015) shares that learners should have many opportunities to “ask questions about, investigate, and seek to explain phenomena, as well as to apply their understanding to engineering problems” (p. 26). Krajcik et al. (2014) show how performance expectations aid in determining what learners ought to know and how they should use such knowledge.

There is research related to these ideas. Elbaum, McIntyre, and Smith (2002) suggest using “rich, relevant activities” (p. 54). Selco, Bruno, and Chan (2012) share a chemistry laboratory experience where online students work with chemicals from the store. This experiment helped students use chemicals and design scientific studies in a safe way. The advantages identified by the researchers were that students liked the activity, came up with their own questions, and had experiences they remembered later

(Selco, Bruno, & Chan, 2012). Heui-Baik, Fisher, and Fraser (1999) explored the impacts of moving to a more constructivist approach with a focus on problem solving in science education in Korea. Korea developed a new national science curriculum to decrease required knowledge and focus on problem solving (Heui-Baik, Fisher, & Fraser, 1999). The results of their study on 10^{th}- and 11^{th}-grade science courses showed science curriculum reform in Korea towards more problem-solving approaches had a positive impact on student attitudes and achievement in science.

The laboratory introductions are for students to complete before working on online course laboratory activities. They could help focus learners on concept knowledge, procedures that promote higher-level thinking through active learning, and analysis through the focus SEPs. They can be a resource to students as they participate in laboratory activities to achieve the highest levels of thought.

Resources

Resources are important in both online course design and teaching. Students in online classes should have access to multiple learning resources and materials that enhance content (iNACOL, 2011a). Furthermore, an online teacher should be able to utilize new technology and a variety of tools and resources (iNACOL, 2011a).

The importance of resources is a key idea in research studies. Reisetter and Boris (2009) found “online resources being useful to 83%, and regularly used by 81%” of the students in their study (p. 167). Zhang (2005) research results showed that courses with multimedia provided “more learner-content interaction, learning performance and learner satisfaction” (Zhang, 2005, p. 159). The best Michigan Virtual School teachers offer many ways to experience content and the tools needed to meet the needs of all students

(DiPietro et al., 2010). A study of gifted students and teachers by Thomson (2010) revealed that it is important to offer students valuable and suitable resources, especially because students often value more than one way to explain a topic. Barbour (2007) recommends easy course navigation with a diversity of ways to deliver content information to engage students. Elbaum, McIntyre, and Smith (2002) also advocate making templates and structuring course items in an organized manner while using graphics and animations to support learning.

Visual aids can be a valuable way to illustrate concepts for students (Thomson, 2010). Schmidt (2009) specifically describes the benefits of visuals on learning by saying it improves educational experiences by allowing what cannot be seen to be visualized. She lists some examples used in her undergraduate Introduction to Food Science and Human Nutrition class. These include detailed explanatory images, video and animation clips, anthropomorphic images, cartoons, demonstrations, experiments, and performances (Schmidt, 2009). Cys (1997) discusses the use of graphic organizers, visual symbols, word pictures, and presentations to help learners visualize what is being communicated. Jeschofnig and Jeschofnig (2011) outline some ways to deliver content to online laboratory science learners. They say to completely involve all learners in classes, activities ought to be very interactive (Jeschofnig & Jeschofnig, 2011). Interaction with content can come from "audio files, video clips, imbedded links, journal articles, simulations, and online tutorials that address the needs of auditory, visual, and kinesthetic learners" (Jeschofnig & Jeschofnig, 2011, p. 74).

When multimedia resources are added to a class, they ought to be added considering best design principles. Mayer (2001) and Clark and Mayer (2011) share principles about designing multimedia for learning. When making the introductions I focused on some of these principles, mainly using both words and pictures, placing corresponding words and pictures together, excluding extra words and pictures, using animation and narration use instead of animation and text use, avoiding redundancy, being conversational and friendly in my narration, chunking appropriate segments, and preparing students for multimedia (Figure 7).

Figure 7. Focus Principles of Multimedia Learning

The design principles of contrast, alignment, repetition, and proximity (CARP) can help improve the quality of design (Lewis, 2000) (Figure 8). Contrast is making various elements different to show they are not the same (Williams, 2004). Good contrasts help attract readers (Williams, 2004). Alignment allows the page to look united by using a similar layout (Lewis, 2000). This gives the page a clean look (Williams, 2004). Repetition of fonts, colors, etc. can add unity, organization, and interest to a presentation (Lewis, 2000). Proximity involves putting similar items close together on a page to show they are related and making the page organized and clear (Williams, 2004).

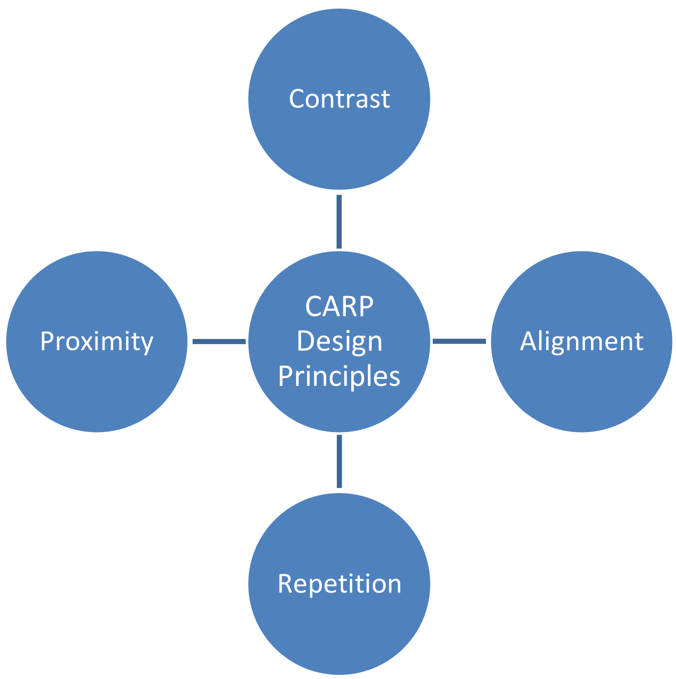


Figure 8. CARP Design Principles

Introductory assignments before each laboratory can allow for teacher creation of and student use of targeted multimedia to best educate students about content, laboratory procedures, and NGSS science and engineering practices. As I designed each introduction, I incorporated Mayer’s multimedia principles and the CARP design principles. This was done to make the introductions easy to understand and beneficial to student learning.

Accessibility

Accessibility is another important area in online course design and teaching standards. iNACOL (2011a) shares that coursework should be made so that all students have access. Course design should follow universal design principles, meet U.S. Section 504 and 508 requirements, and W3C's Web Content Accessibility Guidelines. Maryland Online (2016) supports this saying that course materials should meet the needs of learners and facilitate ease of use. With respect to teaching standards, online teachers should be aware of and comprehend the Americans with Disabilities Act (ADA), the Individuals with Disabilities Education Act, the Assistive Technology Act, Section 508, and other guidelines for accessibility (iNACOL, 2011b).

The Americans with Disabilities Act (ADA, n.d.) ensures equal opportunities for individuals with disabilities. The Individuals with Disabilities Education Act (IDEA) requires schools to provide a free education to students with disabilities in the least restrictive way while meeting student needs. Section 504 of the Rehabilitation Act mandates that people with disabilities not be excluded from programs that receive federal funding, and Section 508 of the Rehabilitation Act necessitates that electronic and other technology that is made, sustained, acquired, or used by the federal government be accessible to those who have disabilities (U.S. Department of Justice, 2009).

W3C (2018) put together documents entitled Web Content Accessibility Guidelines (WCAG) 2.0 and 2.1 with ways to help online materials be more accessible to learners. Additionally, McGrath (2016) has checklists available to help designers meet accessibility requirements. There are three types of checklists, Level A (beginner), Level AA (intermediate), and Level AAA (advanced).

When creating the introductions, accessibility was of utmost importance. I created alt tags for pictures and offered video, audio, and text. I also worked to organize information in a logical order, carefully considering colors, fonts, and texts.

Copyright

A final concern is copyright law. The iNACOl (2011a) course design standards state that copyright and licensing status for all course content must be explained and easy for course users to find. Maryland Online (2016) shares that all content inside of an online class must be cited properly. Online teachers must be capable of following laws related to intellectual policy and fair use (iNACOL, 2011b).

The U.S. Copyright Office (2016) has published a summary of all laws related to copyright. Copyright protection extends to literature, music, drama, choreography, pictures, video, sound, and architecture (U.S. Copyright Office, 2016). Authors of copyrighted works can exclusively copy, make derivative work, hand out copies, make performances, and deliver audio. Some items and uses are allowable under copyright law because they fall under fair use or their authors have made them acceptable to use. Creative Commons (n.d.) is one resource that provides legal help to people wanting to share their work with others and can be a good source for usable materials.

When creating introductions, I adhered to copyright law. I designed my own materials or properly cited others when linking to outside resources.

Interactions

Interactions are critical in online learning. Online courses should allow for instructor-student interaction with frequent feedback (iNACOL, 2011a). Assignments ought to offer ways for interaction to occur and facilitate learning (Maryland Online, 2016). Additionally, the instructor should know how critical interactions are, be able to use tools to communicate with students, and develop opportunities for teacher-student interaction (iNACOL, 2011b).

Class interactions can be between students, students and content, students and teachers, teachers and content, teachers, contents, students and groups, and teachers and groups (Anderson, 2008). Learner-content interactions occur as students construct knowledge with new information (Moore, 2005). Anderson (2008) adds that some content can be interactive to adjust to student needs. Teachers and students can interact to interest students in learning, help students apply content, evaluate work, and assist students (Moore & Kearsley, 2005). Teachers can interact with content by designing course materials (Anderson, 2008). For this study, the focus interactions were between students and the teacher, students and content, and the teacher and content.

Interactions can happen through assessments. Teachers can utilize assessments when designing lessons, and students can use them when determining what they ought to learn. Formative assessments can happen throughout classes to help instructors gauge learning at any time (NRC, 2000). The NRC (1996) recommends students have access to a variety of assessment methods to gain information about all types of learning. Cox-Peterson and Olsen (2012) further explain that feedback ought to provide information about certain concepts and allow for an increase in conceptual understanding. It is through feedback that mental adjustments are made and conceptions of knowledge are corrected.

Teacher, student, and content interactions can be a good way to provide students with valuable information. DiPietro et al. (2010) discuss that exemplary online instructors watch student progress and interact with students to figure out where learning needs to be improved. Phipps and Merisotis (2000) state that learner interactions with instructors are needed in online courses. Cohen and Ellis (2004) found "effective instructor-to-student feedback" to be a principal factor for students and faculty (p. 166). Reeves, Vangalis, Vevera, Jensen, and Gillian (2007) discuss the importance of offering parents and students good communication, observing student work, grading often, giving positive feedback, offering tutoring, organizing assessments, and establishing community.

By adding introductory activities before laboratory assignments, students have the opportunity to interact with key concepts, procedures, and the focus SEPs. They also can ask the instructor questions as they prepare to learn science knowledge and complete laboratory activities. As the teacher interacts with students and content, s/he may be better able to meet the needs of all learners.

Online Laboratory Design and Best Practices

With a shift towards the NGSS, there has been a new focus on practices (Berland, Schwarz, Krist, Kenyon, Lo, & Reiser, 2016). The use of the word practices expresses that both skill and knowledge are necessary when completing scientific investigations (NRC, 2012). The NGSS SEPs allow students to see how scientific knowledge is formed, makes knowledge more meaningful, and promotes student interest. Focusing on practices allows students to move beyond just completing activities and begin to construct knowledge determinedly (Duncan & Cavera, 2015).

According to Berland et al. (2016), students can learn how the scientific community works and increase their personal engagement with practices by focusing on meaningful ideas for both the science community and classrooms. They state that the NSTA has resources available online to help teachers implement the use of practices in the classroom. There is also a variety of other literature about how to have students engage in science and engineering practices. For example, Reiser, Berland, and Kenyon (2012) show ways to engage students in the practices of argumentation and explanation. They highlight how students can participate in meaningful activities and consensus building through the practices. Rinehart, Duncan, and Chinn (2014) also share how scaffolding model-based activities about reasoning allow students to more successfully incorporate logical thinking into their science work.

Laboratory Activities

With the importance of SEPs highlighted in the NGSS (2013b), I began to think how these practices can be better achieved in the online science classroom. My ideas quickly turned to utilizing laboratory activities to promote the SEPs of the NGSS. Jeschofnig and Jeschofnig (2011) state that laboratories are critical in science even when courses move online. This is because students should become aware of experimental design and activities. Furthermore, it is important for students to observe, make inferences, and develop skills to do science experiments and analyze results. They highlight a variety of ways to add laboratory activities to online courses (Jeschofnig & Jeschofnig, 2011)

Science Simulations and Virtual Laboratories

Science simulations and virtual laboratory opportunities harness the power of technology to deliver laboratories. There is a difference between virtual and simulation laboratories (Crippen, Archambault, & Kern, 2013). Virtual laboratories require setup followed by working with equipment that is not real, data collection, and data analysis. Simulations do not require setup. They are computer-based, interactive activities (Jeschofnig & Jeschofnig, 2011). Students generally enjoy these experiences, which have the advantage of being inexpensive and safe while achieving objectives and preparing students for actual laboratories (Jeschofnig & Jeschofnig, 2011). However, due to their development cost, high school students rarely receive the level of complexity necessary to adequately teach topics through these activities. Other negatives are these laboratories may not meet all learning objectives, don't allow for touch, and are passive (Jeschofnig & Jeschofnig, 2011).

Simulation activity design can vary. One way to offer simulation laboratory activities is through the use of archived data (Ucar & Trundle, 2011). The research of Ucar and Trundle (2011) showed that using archived data about tides for preservice teachers allowed students to easily access data from a large time frame. Another way to use simulations is to enhance courses (Lamb & Annetta, 2013). In the Lamb and Annetta (2013) study, their treatment group had course enhancements via simulations. In this study, the simulation laboratory enhancements improved student understanding of and positive perceptions about science (Lamb & Annetta, 2013).

Hands-on Laboratories

Hands-on laboratories require physical setup and the use of equipment to collect and analyze data as hands-on, real world experiments (Crippen, Archambault, & Kern, 2013). Kitchen science laboratories allow online students to complete laboratories at home (Jeschofnig & Jeschofnig, 2011). Kitchen laboratories offer hands-on laboratory experiences, compare science to the world, meet objectives, and reduce course costs. However, these laboratories can be simplistic, as well as bring up student costs, require student time, and create safety concerns. Yet, a study of online nonmajors biology showed that a safe and engaging laboratory experience is achievable with home laboratories (Mickle & Aune, 2008). Another way to offer hands-on laboratory experiences in the online environment is through instructor-assembled or commercially-assembled laboratories or hybrid courses (Jeschofnig & Jeschofnig, 2011).

Remote Laboratories

Remote laboratories are another option for online courses. Crippen, Archambault, and Kern (2013) describe remote experiments as not needing setup, but allowing users to virtually operate equipment as well as collect and analyze data. Remote access laboratories let students utilize real equipment at a distance with advantages and disadvantages (Jeschofnig & Jeschofnig, 2011). Some of the advantages are that such experiences enhance physical laboratories, allow for technology use, help maximize safety, and can meet many objectives. Nickerson, Corter, Esche, and Chassapis (2007) say that those who support remote laboratories believe they are able to lower costs, the amount of needed space, and the time spent on laboratories. However, there can be issues with limited availability, additional planning requirements, increased costs, and unmet learning objectives.

Current Usage

All online laboratory types are not used equally. Crippen, Archumbault, and Kern (2013) completed a study to determine which types of laboratories online teachers are using and how often laboratories are being used. This was done by surveying secondary teachers of online science courses. The teachers answered that online students spent about 90 minutes a week completing laboratories. Hands-on activities occurred the most, or 48% of the time, followed by simulated (26.7%), and virtual (25.3%) laboratories. However, they did note some teacher ambiguity when categorizing laboratory activities. Their findings further indicated that even laboratories centered on learners had a high degree of teacher direction and lacked much collaboration (Crippen, Archumbault, & Kern, 2013). This caused the laboratory experiences to fail at showing the nature of science. Additionally, they recognized a lack of communication during online laboratories (Crippen, Archumbault, & Kern, 2013). This led them to recommend better designing laboratory activities to involve more collaboration and authentic activities.

With so many online laboratories available to students, adding introductions before the simulation and hands-on laboratories of the study course may help students achieve more benefits from their online laboratory experiences. Through well-designed introductions to accompany laboratory activities, students can learn more about the expectations of the labs, focus on its key ideas, understand the activities, and engage with the focus SEPs. They can also interact with the teacher and the content before beginning the laboratory activities to maximize their online laboratory experiences.

Online Laboratory Effectiveness

After considering the diverse types of online laboratories available for student use, it is important to explore them further. There are a variety of comparison studies of K-12 students and simulation laboratories. A study by Pyatt and Sims (2011) submits that students in physical and virtual first-year secondary chemistry classes had comparable results on knowledge tests. Another example is research by Klahr, Triona, and Williams (2007), which involved middle school students creating hands-on virtual race car projects. They again determined that students were able to learn with both virtual and physical materials. Finally, research by Shegog, Lazarus, Murray, Diamond, Sessions, and Zsifmond (2012) showed that a transgenic mouse model virtual activity was effective at increasing both the procedural and declarative knowledge of advanced placement biology students when compared to instruction without the use of the simulation.

Beyond K-12 instruction, comparison studies looking at instructional outcomes occur at the undergraduate level as well. Lin, Liang, and Tsai (2012) survey results showed that Internet physiology instruction students experienced more agreement with sophisticated conceptions, suggesting a deeper understanding of topics than the traditional instruction group. Gilman (2006) demonstrated that online labs are effective for learning with results showing that undergraduate students performing the laboratory online did better on a content quiz after simulation laboratory assignments than students physically completing the laboratory. Swan and O’Donnell (2009) showed virtual laboratory participants scored better than non-users on practical laboratory testing and knowledge questions. Finally, Stuckey-Mickell and Stuckey-Danner (2007) surveyed college students with Likert-like and open-ended questions after students used simulations and face-to-face laboratories during their online introductory biology classes. Their study results showed that the majority of students (86.9%) preferred face-to-face laboratories, but 60.5% of students also thought virtual laboratories helped with their learning.

Furthermore, there was a study of a variety of research. This study showed that 49 of 61 studies "demonstrated positive impacts of the use of computer simulations, either as descriptive studies or in comparison with more traditional methods" (Smetana & Bell, 2012, p. 1356). Eleven other studies showed no conclusive results or a lack of differences. Smetana and Bell (2012) explain that "computer simulations can be particularly appropriate for teaching a variety of scientific process skills, including visualization, classification, data interpretation, problem-solving, and experimental design." (p. 1357). Furthermore, they advocate using simulations in addition to other modalities of teaching to offer learner support and encourage cognitive dissonance.

Research by Reeves and Kimbrough (2004) compared at-home with traditional laboratories. They designed an introductory chemistry course with at-home laboratory activities and determined if students learned by using course grades and laboratory practical results in the areas of procedure, data presentation, data analysis, and overall. Their results showed that home laboratories can allow students to experience learning results similar to traditional laboratories (Reeves & Kimbrough, 2004).

Lundsford (2008) looked at guided inquiry with an online college biology course where all but one laboratory took place online at home. Thirteen students participated in 15 laboratories. Students developed research questions and worked to make and evaluate hypotheses. The study revealed that most students were able to develop "covariation questions similar to those asked by practicing scientists" (Lundsford, 2008, p. 14). Hypotheses quality varied, but "they were all clearly stated and testable" (Lundsford, 2008, p. 15). Lundsford (2008) concluded that "the results of this research clearly show that rich socially-based participation in scientific inquiry is possible in the modern age of online instruction." (p. 20).

Nickerson et al. (2007) studied the use of remote laboratories in physics. Students completed three laboratories in a face-to-face format and three laboratories remotely. The researchers collected data related to test scores, laboratory grades, and preferences. They found that "more than 90% of the student respondents rated the effectiveness and impact of remote labs to be comparable to (or better than) the hands-on labs" (Nickerson et al., 2007, p. 721). Assessments related to laboratory-specific material confirmed this finding (Nickerson et. al., 2007).

There are studies showing the effectiveness of both remote and at-home science laboratories. Brinson (2015) recently completed a review of the literature on these laboratories. He was able to determine that of 50 post-2005 articles, the majority showed students achieved equal or better results using non-traditional laboratories when compared to traditional laboratory results. However, most of these articles looked at content knowledge while inquiry skills and laboratory reporting only received exploration in a small number of studies.

Johnson (2002) compared the learning of Bio 100 online students with those completing the course in the traditional format. The online format included inquiry–based, hands-on laboratory assignments to be completed at home. Post-test results and attitudinal surveys revealed that "online students were as successful as on-campus students at acquiring an understanding of biology content, acquiring graphing skill, increasing reasoning ability, and developing positive attitudes towards science." (Johnson, 2002, p. 314). Another study by Reuter (2009) comparing an online and traditional soil science course showed no statistical difference between students participating in the two course formats.

Online laboratories can be studied for more than learning outcomes. Clark (2012b) suggests a good way to analyze online programs is by studying curriculum and teaching methods to determine how they impact "student and teacher values for what is learned" and "subsequent motivation to teach and learn and to use what is learned outside of the instructional setting." (Clark, 2012a, p. 219). A study by Pyatt and Sims (2011) attributed similar instructional value to both laboratory simulations and actual laboratory experiences as students found virtual laboratory activities to be rigorous and authentic. Swan and O'Donnell (2009) work suggests that users have more positive attitudes towards virtual laboratories. However, other research by Gilman (2006) cites mixed student reactions to the simulation laboratories.

Other areas to consider about distance learning programs are access, utilization of resources, and the reliability of the technology (Clark, 2012b). According to Scalise, Timms, Moorjani, Clark, Holtermann, and Irvin (2011) some benefits to simulation laboratories include lowering laboratory costs, lowering laboratory time, providing "green" alternatives, increasing laboratory access for rural schools, and providing opportunities for poorer districts. On the other hand, Scalise et al. (2011) cite access to technology, technical problems, and connectivity issues as concerns with simulation laboratory assignments. These studies show that online laboratories might have the capability of increasing student access and maximizing the use of available educational resources.

The laboratories for the online course in the study are simulations and at-home laboratories. Therefore, based on the previous research highlighted above, such laboratories have the potential to offer online students enriched science experiences. The use of laboratory introductions focused on content, procedures, and the focus NGSS SEPs may help students better complete laboratories and achieve even more positive learning experiences.

Online Laboratory Design

In light of the fact that online laboratories have the potential to offer positive learning outcomes, are often liked by students, increase access, and maximize the efficient use of resources, the question becomes how can these activities be designed to provide maximum benefits to student learning. Science classes should allow for multiple laboratories as this will allow students the opportunity to organize and access data (Scalise et al., 2011). Effective online laboratories begin with the design of laboratory experiments. However, in one study of laboratory assignments, von Aufschnaiter and von Aufschnaiter (2007) found that it is important to consider what kinds of interactions happen during laboratories. They also suggest that laboratory teaching should center on the creation of good learning opportunities where such activities promote conceptual understanding instead of just linking previous understanding to practice (von Aufschnaiter & von Aufschnaiter, 2007).

Higher Level Thinking

A key idea in science instruction has been the use of higher level thought processes. Inquiry laboratories help students form questions and look for answers to questions (NRC, 2000). The NRC (2000) states that most children can learn through inquiry because they are curious by nature, can engage their curiosity, and hold on to concepts learned this way. The NRC (2000) goes through an example of inquiry in the classroom and compares it to what a scientist might do in the field. Some ideas highlighted in the classroom example are that inquiry activities allow students to "exhibit curiosity, define questions from current knowledge, propose preliminary explanations and hypotheses, plan and conduct simple investigation, gather evidence from observation, explain based on evidence, consider other explanations, and communicate explanation" (NRC, 2000, pp. 7-8). Inquiry can be promoted with simulations through the use of fewer directions, opportunities for reasoning, and engaging students with authentic connections (Perkins, Loeblein, & Dessau, 2010).

There is research related to the effectiveness of inquiry in laboratory experiences. Through a study by Areepattamannil (2012), adolescents in Qatar showed the positive impact of model-based and interactive inquiry science on student learning and interest. However, positive learning impacts were not seen with the use of "student investigations and hands-on activities" (Areepattamannil, 2012, p. 142). This caused the author to conclude that there is evidence to suggest an emphasis on models or applications and interactions can improve literacy and student desire to learn science (Areepattamannil, 2012). Inquiry-based instruction for middle and high school showed significantly higher scores on both the proximal and distal test items when compared to traditional experiences (Lui, Lee, & Linn, 2010).

Comparing active learning through “traveling laboratories” with traditional instruction via more traditional resources, Taraban, Box, Myers, Pollard, and Bowen (2007) showed that more active laboratories led to improvement in fact recollection and understanding of process skills. However, “there was only suggestive evidence of student gains” in critical thinking (Taraban et al., 2007, p. 975). Kang, DeChenne, and Smith (2012) observed scientific questioning as well as student approaches to inquiry instruction of high school students in environmental health science. They used writing samples to show that after ten weeks with curriculum utilizing inquiry, “students became active inquirers by asking more questions about data analysis and sought explanations in terms of correlations or causal relations in the case” (Kang, DeChenne, & Smith, 2012, p.155). While studying the surveys and interviews of tutors, adult learners, and experts in educational games and simulations, de Freitas (2006) found that 85% of respondents thought that games and simulations in education facilitated understanding of complex concepts. The experts surveyed recommended such activities for problem-based learning, constructivist approaches, and higher order learning (de Freitas, 2006).

In addition to helping enhance student performance, inquiry labs may also increase student interest. The study by Taraban et al (2007) showed students learning through inquiry had more positive attitudes about learning science. In a Hofstein, Nahum, and Shore (2001) study of high school chemistry students, the group inquiry activities focused on “asking relevant questions, planning an investigation, hypothesizing, observing, and recording phenomena” (Hofstein, Nahum, & Shore, 2001, p. 200). Their results showed that students had a preference for inquiry (Hofstein, Nahum, & Shore, 2001). Furthermore, students expressed that they were “more involved” in open-ended instructional experiences (Hofstein, Nahum, & Shore, 2001, p. 205).

By focusing on the NGSS SEPs for laboratories, laboratories can become more centered on scientific and engineering practices and the development of science knowledge and higher-level thinking. The use of introductions to the NGSS SEPs can help with focusing laboratories on higher levels of thinking. This may lead to a corresponding increase in student use of and interest in the focus NGSS SEPs to improve laboratories.

Authentic Activities

Authentic activities are important in laboratories as students have the opportunity to investigate real-life, relevant experiences. There is a need for authentic activity in relation to simulation activities as opposed to just multiple-choice and open-ended construct questions (Scalise et al., 2011, p. 1064). Simulation laboratories ought to be “based on real events and data” (Blake & Scanlon, 2007). They should involve the “use of multiple representations, graphs, and an opportunity to observe any graphs forming while an experiment is running (in real time).” (Blake & Scanlon, 2007, p. 499). Smetana and Bell (2012) explain that “computer simulations can be particularly appropriate for teaching a variety of scientific process skills, including visualization, classification, data interpretation, problem-solving, and experimental design.” (p. 1357).

Through activities that often mirror games, students can examine authentic experiences and the related science (Perkins, Loeblein, & Dessau, 2010). They discuss that simulations can be interactive, allow for inquiry, minimize the need for dangerous or expensive equipment, open up new laboratory opportunities, help students easily change variables, conceptualize what cannot be seen, provide a similar way for the class to picture ideas and then communicate, offer learning beyond the classroom, and create opportunities for exploration (Perkins, Loeblein, & Dessau, 2010).

Mawn, Carrico, Charuk, Stote, and Lawrence (2011) studied how "online students engaged in scientific processes as they conducted relevant and real-world experiments from their own locations." (p. 135) The study took place with undergraduate students of three courses designed for content relevance and rigor, authenticity and relevance in learning activities, interaction and multiple sources of media, and math and science literacy. The researchers collected surveys related to the hands-on online labs they studied. The results demonstrated that learners engaged in science processes when completing these online, at-home laboratories. However, they do recommend increasing the open-ended nature of assignments so that students will consider questions and further investigate during the laboratories. A last idea is to focus on process-related goals for learning.

Support

Support can be a critical design component for students during laboratories. Scaffolding and visualization can increase student understanding of simulations and using the inquiry process (Scalise et al., 2011). A study about guiding high school students through the laboratory reporting process tested the impact of instructional support (Porter, Guarienti, Brydon, Robb, Royston, Painter, Sutherland, Passmore, & Smith, 2010). Instructional support through checklists and in-class discussions led students to write better laboratory conclusions (Porter et al., 2010). Another study of an undergraduate biology class showed the importance of teacher guidance in science laboratory instruction (D’Costa & Schlueter, 2013). The results of the study showed that teachers should “provide explicit and scaffolded instruction” of the science process skills needed for inquiry (D’Costa & Schlueter, 2013, p. 22). Simulations should offer ways “to tailor activity to student ability levels.” (Blake & Scanlon, 2007, p. 499). Some accommodations of different learning levels can occur through helpful notes and online support.

In research about an online field experience in a graduate geology course, 73% of learners felt positive about using Google Earth, while some had trouble with the program. After reviewing all data, the authors recommend adding videos, examples, and reducing the number of landforms for identification to manageable levels to make the experience less difficult for some students (Clary & Wandersee, 2010).

Finally, factors of importance to students in at-home laboratories emerged from the work of Reeves and Kimbrough (2004). These include course organization, relevance by using home materials, quizzes and homework, and laboratory report writing to make ideas more clear and understandable.

From this section, it is clear that it may be possible to improve online laboratories by adding opportunities for higher level thinking, authentic activities, scaffolding, support, visualizations, multiple modes of representations, and organization into learning blocks. Introductions with the use of content explanation, additional resources, and interactive activities may provide these to help students complete laboratory science activities and engage with and use the SEPs of the NGSS.

Chapter Summary

In conclusion, there were many factors considered when designing the introductions for this research. Online standards, science standards, and supporting research guided the design of the laboratory introductions. Based on the literature review, I posited that the introductions could have a positive impact on student completion of laboratories and student use of and interest in the focus SEPs of the NGSS. The next chapter analyzes the results of the study.

CHAPTER THREE: METHODS

This chapter provides a summary of the methodology for the research study, which was an exploratory mixed methods research project. It includes the research questions, research methods, data collection, data analysis, validity, reliability, and study considerations.

Research Questions

The study answered four research questions: Do introductions before online forensic science laboratories focused on key content, procedures, and two NGSS SEPs (analyzing and interpreting data and constructing explanations and designing solutions) promote (1) student interaction with the course instructor, (2) student completion of laboratories, (3) student thinking about the NGSS SEPs, and (4) student use of those NGSS SEPs in laboratory responses?

Research Methods

The research design was an exploratory mixed methods study, including both quantitative and qualitative data (Creswell, 2012). This type of design was best suited for this study because it allowed for a deeper exploration of the impact of the intervention. I, as the teacher researcher, studied my own class. This research included archived data from a previous course (fall 2016 comparison) as I considered the need for the study and an intervention class (fall 2017) to explore the impact of introductions to online laboratories on student laboratory questions, completion, and thoughts about and use of two NGSS SEPs (analyzing and interpreting data and constructing explanations and designing solutions).

There were four simulation laboratories and eight at-home laboratories in the course that were a part of the study. The intervention group had introductions to the laboratories focused on key content, procedures, and the two focus NGSS SEPs (Appendix A). Data collection, data analysis, and conclusions followed the intervention. The study timeline was as follows (Table 3.1)

Table 3.1 Study Timeline

Data	Treatment
Pre-Study Survey	September 2017
Pre-Study Evaluation of Previous Course	September 2017 - January 2018
Introductory Assignments	September 2017 - January 2018
Laboratory Assignments	September 2017 - January 2018
Rubric Evaluation	September 2017 - January 2018
Post-Study Survey	January 2018

In unit 2 of the course, students completed the pre-study survey I designed after reviewing the focus SEPs and failing to find a published survey to use (Appendix B). I also designed a post-study survey to align with the pre-study survey I made (Appendix C). I included introductions related to the content, procedures, and the NGSS SEPs of focus before each laboratory. I recorded any student questions about each introduction. After having the chance to work on each introduction, students completed the current course laboratory assignments. I analyzed laboratory assignment answers using completion rates, scores from the researcher rubric (Appendix D) specifically designed for the research project, laboratory report work, and laboratory scores. Finally, students completed the post-course survey in unit 8.

Participants

I used convenience sampling for the study. I chose the sample because the registrar assigned these students to me. The 51 participants included students enrolled in Forensic Science at an online school in the Northwest. I, as the course instructor, taught the intervention class (fall 2017) asynchronously via Blackboard and also used an archived comparison course (fall 2016) for additional course completion and laboratory score data.

There were 30 fall 2017 intervention group and 21 fall 2016 comparison group participants. The intervention group included 83% females and 17% males, while the comparison group had 57% females and 43% males. Seventy percent of the intervention class participants were high school juniors or seniors. Correspondingly, 90% of the comparison (fall 2016) were juniors and seniors in high school (Figure 9). The majority, or 83% of the intervention class (fall 2017), took the class due to the lack of local offerings, for early graduation, or because of scheduling conflicts. Most of the students in the comparison group (95%) took the class because it was not offered locally or due to scheduling conflicts (Figure 10). Ninety percent of the intervention (fall 2017) students passed the class while only 76% of the comparison group (fall 2016) passed the class (Figure 11).

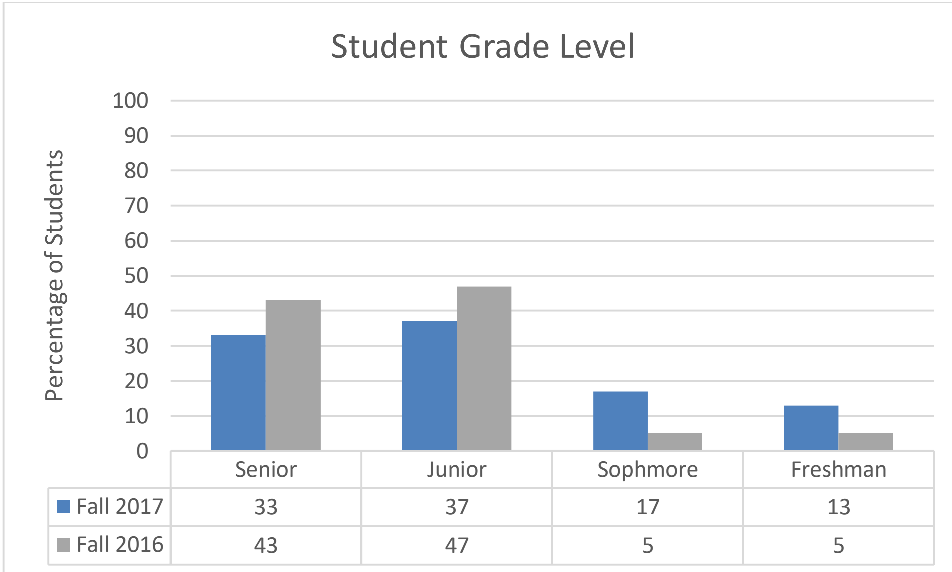


Figure 9. **Comparison and Intervention Group High School Grade Level**

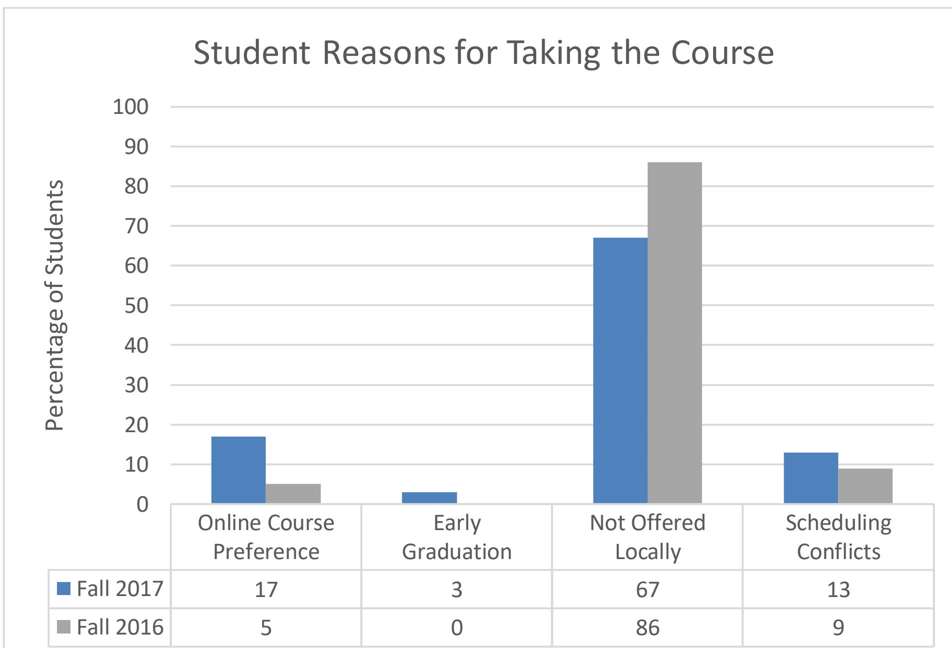


Figure 10. **Comparison and Intervention Group Reasons for Taking the Course**

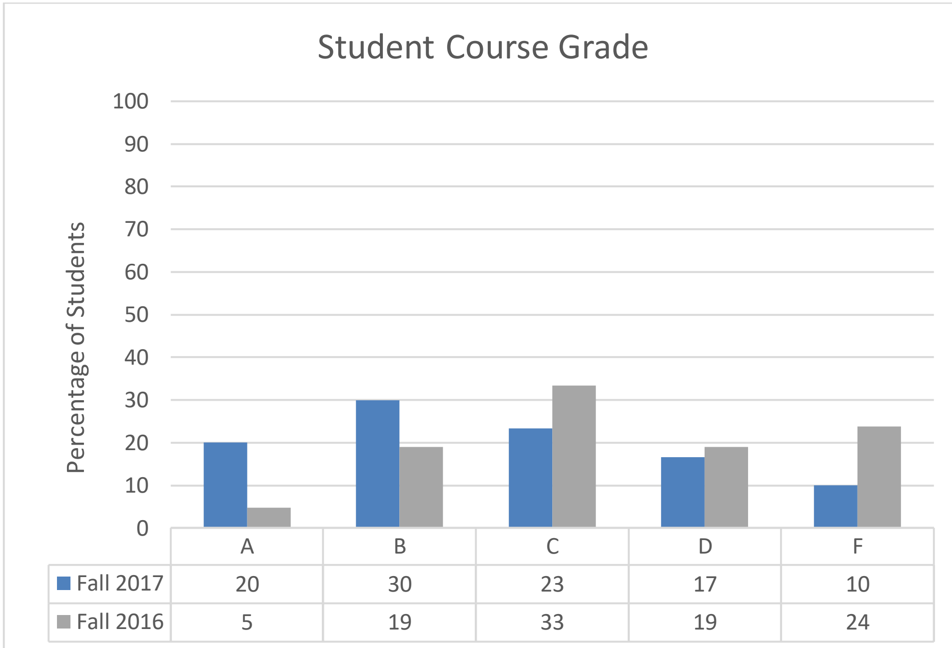


Figure 11. Comparison and Intervention Group Course Grades

<u>School</u>

The school was a virtual school in the Northwest. The school offers the courses asynchronously via Blackboard (Blackboard Inc, 2018). Home districts must have a site coordinator available to work with students and proctor final exams. Students from around the state are able to enroll in courses with help from their local school district. Students can register for the school's courses for a variety of reasons and can receive variable levels of support from their home district. The virtual school assigns course grades, and then the home school district issues that grade to the student.

<u>Course</u>

Apart from the intervention, all other components of the course remained similar to previous course offerings. The course covered the content related to high school forensic science. The curriculum designers at the study school developed the course with materials from Brennan Sapp (n.d.). Brennan Sapp is a former forensics instructor that created curriculum and placed it online for educational use. The course topics were introduction and physical evidence, glass and soil evidence, fingerprint evidence, hair and fiber evidence, firearms and ammunition, drug evidence and classification, chemical analysis of evidence, and DNA and autopsy evidence (Table 3.2). Each unit included online textbook readings, discussion board posts, laboratory assignments (Table 3.3), class assignments (student projects, online activities, and quizzes), and online tests.

All online coursework was based on state standards with a variety of multimedia to deliver topics. My facilitation of learning occurred by email, telephone, and an online science e-tutoring help center. I had the ability to modify some aspects of the course to better facilitate student learning. More significant changes required curriculum team approval. The course was fully online and delivered asynchronously via Blackboard, an online learning management system (LMS), used to deliver online courses. Students were able to submit assignment corrections and turn in late work for reduced points. Only the final examination required a proctor.

Table 3.2 Forensic Science Content Knowledge

Introduction and Physical Evidence
Glass and Soil Evidence
Fingerprint Evidence
Hair and Fiber Evidence
Firearms and Ammunition
Drug Evidence and Classification
Chemical Analysis of Evidence
DNA and autopsy evidence

Table 3.3 Laboratory Types and NGSS SEPs in Each Unit

Unit and Forensic Science Content	Lab Name	Type of Lab	Analyzing and Interpreting Data	Constructing explanations and designing conclusions	Summary
Unit 1 Introduction and Physical Evidence	pH	Simulation	Effectively uses tools, technology, and/or models to make valid and reliable scientific claims or determine optimal design solutions	Effectively use quantitative and/or qualitative claims to explain the relationship between independent and dependent variables; Effectively uses a variety of valid and reliable sources to make explanations	Determining the pH of various substances and determining the impact of adding water
Unit 2 Glass and Soil Evidence	Density	Simulation	Effectively uses tools, technology, and/or models to make valid and reliable scientific claims or determine optimal design solutions	Effectively uses quantitative and/or qualitative claims to explain the relationship between independent and dependent variables; Effectively uses a variety of valid and reliable sources to make explanations	Calculating the density for various substances and whether they float or sink in water

(table continues)

Table 3.3 Continued

Unit and Forensic Science Content	Lab Name	Type of Lab	Analyzing and Interpreting Data	Constructing explanations and designing conclusions	Summary
Unit 2 Glass and Soil Evidence	Soil	At-Home	Effectively uses tools, technology, and/or models to make valid and reliable scientific claims or determine optimal design solutions	Effectively uses a variety of valid and reliable sources to make explanations; Effectively uses scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion; Effectively uses scientific knowledge, student-generated sources of evidence, prioritized criteria and tradeoff considerations to design, evaluate, and/or refine a solution to a complex real-world problem	Comparing different soil samples and shoe imprints
Unit 3 Fingerprint Evidence	Fingerprint Analysis	At-Home	Effectively uses tools, technology, and/or models to make valid and reliable scientific claims or determine optimal design	Effectively uses a variety of valid and reliable sources to make explanations; Effectively uses scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support	Determining fingerprint types and the most common fingerprint type of a group

(table continues)

Table 3.3 continued

Unit and Forensic Science Content	**Lab Name**	**Type of Lab**	**Analyzing and Interpreting Data**	**Constructing explanations and designing conclusions**	**Summary**
			solutions; Effectively uses statistics and probability to address scientific and engineering questions, using digital tools when feasible; Effectively uses limitations of data analysis when analyzing and interpreting data	the explanation or conclusion; Effectively uses scientific knowledge, student-generated sources of evidence, student-generated sources of evidence, prioritized criteria and tradeoff considerations to design, evaluate, and/or refine a solution to a complex real-world problem	
Unit 4 Hair Evidence	Hair Analysis and Mold Making	At-Home	Effectively uses tools, technology, and/or models to make valid and reliable scientific claims or determine optimal design solutions	Effectively uses a variety of valid and reliable sources to make explanations; Effectively uses scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion; Effectively uses scientific knowledge, student-generated sources of evidence, prioritized criteria and tradeoff considerations to design, evaluate,	Observing and explaining the similarities and differences of hair samples.

(table continues)

Table 3.3 continued

Unit and Forensic Science Content	Lab Name	Type of Lab	Analyzing and Interpreting Data	Constructing explanations and designing conclusions	Summary
				considerations and/or refine a solution to a complex real-world problem	
Unit 5 Firearms and Ammunition	Target	Simulation	Effectively uses tools, technology, and/or models to make valid and reliable scientific claims or determine optimal design solutions	Effectively uses a variety of valid and reliable sources to make explanations; Effectively uses scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion	Figuring out how to adjust variables to allow a ball to hit a target
Unit 5 Firearms and Ammunition	Projectile Motion	Simulation	Effectively uses tools, technology, and/or models to make valid and reliable scientific claims or determine optimal design solutions	Effectively uses a variety of valid and reliable sources to make explanations; effectively uses scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion	Measuring the impact of different factors on projectile motion; Designing a laboratory

(table continues)

Table 3.3 continued

Unit and Forensic Science Content	Lab Name	Type of Lab	Analyzing and Interpreting Data	Constructing explanations and designing conclusions	Summary
Unit 6 Drug Evidence and Classification	Drug Data Collection	At-Home	Effectively uses tools, technology, and/or models to make valid and reliable scientific claims or determine optimal design solutions; Effectively uses statistics and probability to address scientific and engineering questions, using digital tools when feasible; Effectively uses limitations of data analysis when analyzing and interpreting data	Effectively uses scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion; Effectively uses scientific knowledge, student-generated sources of evidence, prioritized criteria and tradeoff considerations to design, evaluate, and/or refine a solution to a complex real-world problem	Evaluating drug survey data to develop a drug test kit
Unit 7 Chemical Analysis of Evidence	Red Cabbage pH Analysis	At-Home	Effectively uses tools, technology, and/or models to make valid and reliable scientific	Effectively uses quantitative and/or qualitative claims to explain the relationship between independent and dependent variables; Effectively uses	Identifying the pH of various household substances

(table continues)

Table 3.3 continued

Unit and Forensic Science Content	Lab Name	Type of Lab	Analyzing and Interpreting Data	Constructing explanations and designing conclusions	Summary
			claims or determine optimal design solutions; Effectively uses limitations of data analysis when analyzing and interpreting data	scientific knowledge, student-generated sources of evidence, prioritized criteria and tradeoff considerations to design, evaluate, and/or refine a solution to a complex real-world problem	
Unit 7 Chemical Analysis of Evidence	Chromatography	At-Home	Effectively uses scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion	Effectively uses scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion; Effectively uses scientific knowledge, student-generated sources of evidence, prioritized criteria and tradeoff considerations to design, evaluate, and/or refine a solution to a complex real-world problem	Completing a chromatography assignment using pens; Matching an unknown to a known

(table continues)

Table 3.3 continued

Unit and Forensic Science Content	**Lab Name**	**Type of Lab**	**Analyzing and Interpreting Data**	**Constructing explanations and designing conclusions**	**Summary**
Unit 8 DNA Evidence and Autopsy	DNA Extraction	At-Home	Effectively uses tools, technology, and/or models to make valid and reliable scientific claims or determine optimal design solutions	Effectively uses a variety of valid and reliable sources to make explanations	Explaining the steps of a laboratory; Seeing DNA
Unit 8 DNA Evidence and Autopsy	Blood Splatter	At-Home	Effectively uses tools, technology, and/or models to make valid and reliable scientific claims or determine optimal design solutions	Effectively uses a variety of valid and reliable sources to make explanations	Determining the relationship between surface, height, and blood splatter.

Intervention

Introduction interventions were designed using the www.h5p.org interactive video creation tool, a course presentation template the school recommends for the creation of course materials (H5P, 2017). The website with the introductions did not allow me to track student completion of the introductions. Therefore, I was unable to ascertain exactly how many students participated in all or part of each introduction.

Appendix A has screenshots of a sample introduction. Each introduction intervention being studied included: an introductory slide with the laboratory name and relevance of the laboratory, key content ideas with resource links, interactive questions about key content ideas, procedure summary, interactive questions about procedure summary, information about data analysis, and information about conclusions.

Each introduction design considered Mayer's (2001) and Clark and Mayer's (2011) ideas related to multimedia learning. The principles I made sure to follow in the study were that students learn better from multimedia (both words and pictures), spatial continuity (corresponding words and pictures together in space), temporal continuity (corresponding words and pictures together in time), coherence (the exclusion of extra words and pictures), modality (animation and narration use instead of animation and text use), redundancy (animation and narration instead of animation, narration, and text), personalization (conversational and friendly human narration), segmenting (chunking of appropriate segments), and pre-training (preparation of students for multimedia). When developing the introductions, I considered how the design principles of contrast, repetition, alignment, and proximity can aid in the quality of design (Lewis, 2000).

Accessibility was another area to highlight. When designing the introductions, I reviewed the Americans with Disabilities Act (ADA, n.d.). I also studied the Individuals with Disabilities Education Act (IDEA), section 504 of the Rehabilitation Act and section 508 of the Rehabilitation Act (U.S. Department of Justice, 2009). Finally, I consulted Web Content Accessibility Guidelines (WCAG) 2.0 and 2.1 (W3C, 2018) and McGrath's (2016) accessibility requirement checklists. The items of focus when creating introductions in this study were creating alt tags for pictures, offering alternatives to video and audio, using meaningful content order, providing instructions for more than one sense, not over relying on color, choosing appropriate colors, fonts, and font sizes, making commands workable with the keyboard, creating useful titles, and a logical order.

A final consideration was copyright law. The U.S. Copyright Office (2016) has published a summary of all laws related to copyright. For this study, I concentrated on: linking to websites to ensure proper credit for works, using templates and pictures free of copyright restrictions, taking my own pictures, making my own videos, and giving proper credit to sources.

The introduction design focused on content, procedures, and using selected NGSS SEPs. The two NGSS SEPs examined in detail during the study were: analyzing and interpreting data and constructing explanations and designing solutions. With teacher guidance on content, procedures, and using the two NGSS SEPs, students had help learning how to use science practices and concepts to represent and understand their data. This, in turn, should lead to them making more effective explanations about and design solutions based on their findings. Introductions had audio, videos, transcripts, resource links, graphics, and brief questions introducing students to laboratory content, procedures, and the two NGSS SEPs of focus as they are relevant to the laboratory.

Instruments

The researcher-designed instruments for the study included:

- pre- and post-survey questions to assess student laboratory and introduction completion and interest in the NGSS SEPs (Appendix B & C).
- rubric to evaluate student use of the NGSS SEPs (Appendix D).

The instrument design occurred after reflecting on the NGSS (2013b) SEPs of focus and failing to find a suitable survey and rubric during the literature review.

Data Collection and Analysis by Research Question

I used both quantitative and qualitative data to improve the quality of the study (Table 3.4). The quantitative data allowed me to quantify the numbers and types of questions students asked based on the introductions. It provided information about the differences in completion rates and grades between a previous class and the intervention class and helped me to see changes in the intervention class thoughts about and use over time of the focus SEPs. Then, qualitative data related to survey answers, introductory questions, and laboratory assignments helped me to determine if there were changes in student thoughts about and use of the NGSS SEPs of focus over time for the intervention class.

Table 3.4 Data Types

Data	Data Type
Likert Pre- and Post-Survey Answers	Quantitative
Open-ended Pre- and Post-Survey Answers	Qualitative
Introductory Assignment Student Questions	Quantitative and Qualitative
Laboratory Assignment Completion Rates and Scores	Quantitative
Laboratory Assignment Rubric Scores	Quantitative
Laboratory Assignment Question Responses	Qualitative

Quantitative Data

Quantitative information for the study was related to Likert survey data, the amount of student questions about introductions, and laboratory scores. Quantitative data included:

- Likert pre- and post-survey answers
- descriptive measures about questions before laboratories
- laboratory completion
- laboratory scores
- laboratory rubric scores for the focus NGSS SEPs

Qualitative Data

Qualitative information for the study consisted of open-ended survey data, the types of questions about introductions, and laboratory answers. Qualitative data included:

- open-ended survey answers
- introductory laboratory question analysis
- laboratory report answer analysis

The codes for the study were descriptive (Miles, Huberman, & Saldana, 2014). This means I explained what was seen in the data with a word or phrase. I started with deductive coding (Miles, Huberman, & Saldana, 2014). In other words, I created a list of codes I expected to see in the data. Then, inductive codes developed through the analysis of data (Miles, Huberman, & Saldana, 2014). All codes had a meaning associated with them which was easy to ascertain from the chosen descriptive word or phrase. Throughout the study, patterns in the codes occurred and were identified over time and across questions (Table 3.5).

Table 3.5 Coding Framework

Coding Area	Codes	Description
Questions	Content	Questions about hypothesis development, questions to ask, outcomes of the lab, why the lab was selected
	Data Organization	Questions about how to summarize data, how to fill in tables, charts, descriptions
	Helpful Introductions	Laboratories were well-explained, videos easy to follow
	None	Did not answer the question, answered none
	Procedural – Materials	Questions about what materials are needed, how to get materials, how to substitute materials, alternative labs
	Procedural – Steps	General questions about how to complete the lab
	Procedural - Tech	Questions about how to use the lab technology, emailing work, accessing lab or data
	Procedural – Time	Questions about how long the lab takes, what to do if more time is needed, when it is due

(table continues)

Table 3.5 continued

Coding Area	Codes	Description
Laboratory Non-Completion	Excess Mental Works	The lab/class was too difficult
	Forgot	I forgot about the lab
	Materials	I could not get all the materials
	Never	I would/did not skip a lab
	Technology	I could not use the technology
	Time	I was really busy, I did not have enough time
	Understanding	I did not understand
Studying Science Online	Advantage - Content	I like learning about content, I understood the content
	Advantage – Flexibility	I can work at my own pace and/or have flexibility
	Advantage – Real-Life	I like learning about real-life science and/or possible careers
	Advantage - Resources	I can use the textbook, links, and the Internet
	Disadvantage – Flexibility	I procrastinated due to flexible schedules.
	Disadvantage - Materials	I could not get materials

(table continues)

Table 3.5 continued

Coding Area	Codes	Description
	Disadvantage – Miss Face-to-Face Interactions	I miss having a teacher there for help
	Disadvantage – Miss Hands-on Experiences	I miss hands-on lab experiences
	Disadvantage – Understanding	I did not understand the online labs, the online format was difficult
Laboratories	Advantage - Hands-on	I like setting up labs, seeing what happens
	Disadvantage – Hands-on	I like online labs, not doing a lab at home
	Disadvantage - Labs	I didn't like labs, only liked them when finished, no answer
Practices	Data Organization	Summarizing data, filling in tables, charts, descriptions, note-taking and organizing information
	Procedural – Materials	Getting materials
	Procedural – Steps	Completing the steps of the lab, using equipment, collecting information
	Procedural – Time	Planning for how long it will take to complete the lab
	Understanding	Knowing what you collected, what is happening during an experiment

(table continues)

Table 3.5 continued

Coding Area	Codes	Description
Analyzing and Interpreting Data	Application	Collecting data to prove if a hypothesis is true or false, organizing data for others, understanding a problem, making predictions
	No Answer	Answering I do not know, not answered
	Understanding	Knowing what you collected, what is happening during an experiment
Constructing explanations and designing solutions	No Answer	Answering I do not know, not answered, have to
	Solving	Thinking, finding a solution, explaining
	Understanding	Knowing what you collected, what happened during an experiment

Research Question One

Research question one was: Do introductions before online forensic science laboratories focused on key content, procedures, and two NGSS SEPs (analyzing and interpreting data and constructing explanations and designing solutions) promote student interactions with the course instructor by students asking questions before completing the laboratories? Of interest was whether the introductions influenced the frequency of questions students asked regarding procedures, data analysis, or content.

Measures

These sources of data were used to address the first research question (Table 3.6):

- Pre-survey answers to the following questions from fall 2017 (intervention) students completing the survey I designed (Appendix B).
  - Rate this statement: I like to get teacher help before starting a laboratory.
  - What kind of questions do you usually have about laboratories?
- Intervention class logs
- Post-survey answers to the following questions from intervention students completing the survey I designed (Appendix C).
  - Rate this statement: I think introductions explaining laboratories were helpful.
  - What kind of questions did you ask about the laboratories for this class?

Design

The design for this portion of the study was a within-participant design to learn about interaction expectations and actual interactions of the intervention students with the teacher during the study.

Participants

The participants for this part of the study were the 30 students who received the intervention in fall 2017 and asked questions or chose to respond to the course survey.

Data Analysis

Data analysis for this research question included (Table 3.6):

- Determining the percentage of intervention students who historically liked help before the laboratories and what types of questions they usually need help with.
- Reviewing intervention class logs to determine the number of questions asked before laboratories and the categories of these questions.
- Studying intervention post-survey answers to determine the types of help students needed before completing the laboratories and the percentage of students who found the introductions to be helpful.

Table 3.6 Alignment of Research Questions to Data Collection and Data Analysis

Research Question	Data Collection	Data Analysis	Type of analysis
Do introductions before at home forensic science laboratories focused on content, procedures, and two NGSS SEPs (analyzing and interpreting data and constructing explanations and designing solutions) promote student interaction with the course instructor by asking questions before completing the laboratories?	Questions before laboratories	Analysis of questions for quantity and type	Quantitative and Qualitative
	Likert and open-ended pre- and post-course survey answers	Likert and open-ended survey answers related to introductions and introductory laboratory questions review for percentages and types of student responses	Quantitative and Qualitative
Do introductions before forensic science laboratories focused on content, procedures, and two NGSS SEPs (analyzing and interpreting data and constructing explanations and designing solutions) promote student laboratory completion?	Laboratory assignment scores	Comparison of completion rates and laboratory scores between the study class and a previous class; Comparison of completion rates and scores between the simulation and at-home laboratory scores	Quantitative
	Likert and open-ended pre- and post-course survey answers	Comparison of survey answers between the beginning and end of the intervention class	Quantitative and Qualitative

(table continues)

Table 3.6 continued

Research Question	Data Collection	Data Analysis	Type of analysis
Do introductions before forensic science laboratories focused on content, procedures, and two NGSS SEPs (analyzing and interpreting data and constructing explanations and designing solutions) promote student thinking about those NGSS SEPs?	Likert and open-ended pre- and post-course survey answers	Comparison of survey answers between the beginning and end of the intervention class	Quantitative and Qualitative
Do introductions before forensic science laboratories focused on content, procedures, and two NGSS SEPs (analyzing and interpreting data and constructing explanations and designing solutions) promote student use of those NGSS SEPs in laboratory responses?	Laboratory scores	Determining average laboratory report scores and completion rates for each laboratory	Quantitative
	Laboratory rubric	Determining average laboratory rubric scores	Quantitative
	Laboratory answer analysis	Identifying trends in focus NGSS SEP usage in laboratories	Quantitative and Qualitative

Research Question Two

The second research question for this study was: Do introductions before online forensic science laboratories focused on key content, procedures, and two NGSS SEPs (analyzing and interpreting data and constructing explanations and designing solutions) promote student completion of those laboratories? Of specific attention was whether the introductions influenced intervention student laboratory completion and laboratory scores when compared to the comparison class. Another concern was if there was a difference in completion rates for simulation and at-home laboratories for intervention students.

Measures

Data sources for this second question included (Table 3.6):

- Laboratory assignment scores for all course simulation and at-home laboratories for both the fall 2016 (comparison) and the fall 2017 (intervention) class.
    - The four simulation laboratories were pH, density, target, and projectile motion.
    - The eight at-home laboratories were soil, fingerprint, hair, drug survey, red cabbage, chromatography, DNA extraction, and blood splatter.
- Pre-and post-survey answers to the following questions from intervention students completing the surveys I designed (Appendix B & C).
    - Rate this statement: I will enjoy/enjoyed studying science online.
    - What do you think will be/were some advantages and disadvantages of this online class?

  - Rate this statement: This class has simulation laboratories. Simulation laboratories are laboratories that are done using the Internet. I will like/liked the online simulation laboratories for this class
  - Rate this statement: This class has laboratories to complete at home. I will like/liked the at-home laboratories for this class.
  - What do/did you like best about completing laboratories?
  - Rate this statement: I will complete/completed all the laboratories for this class.
  - What are some reasons why you skipped a laboratory assignment?

<u>Design</u>

This portion of the study had:

- A between-participants design to compare the means for each laboratory completion and laboratory scores between the intervention group and the comparison group.
- A within-participants design to study thoughts about student laboratory completion within the intervention group over time.

<u>Participants</u>

The participants for this part of the study were the 30 students who received the intervention in fall 2017 and the 21 students from the comparison class in fall 2016.

<u>Data Analysis</u>

Data analysis for this portion of the study (Table 3.6) included:

- Comparing laboratory assignment completion rates and scores for the comparison class and the intervention class. This analysis occurred both by comparing percentages of students completing the labs and the laboratory score means between the comparison and intervention group. Then, a t-test helped to determine if there was a statistically significant difference in mean laboratory scores between the intervention and comparison classes.

- Reviewing descriptive graphics for the number of laboratories completed by intervention students
- Comparison of Likert and open-ended pre- and post-survey answers for the intervention class helped highlight additional information about online laboratory completion. I found the percentages and types of responses and compared the means by using a t-test to determine statistical significance. Additionally, I concentrated on student open-ended comments for types and numbers of comments.

Research Question Three

The third research question for this study was: Do introductions before online forensic science laboratories focused on key content, procedures, and two NGSS SEPs (analyzing and interpreting data and constructing explanations and designing solutions) promote student thinking about the NGSS SEPs? Of main concern was what the shifts in thinking were.

Measures

Data sources for this third question included student answers to the following Likert and open-ended pre- and post-survey questions from the surveys I designed (Appendix B & C) for the fall 2017 (intervention) class only (Table 3.6):

- Rate this statement: I like to use tables to make scientific claims or figure out best design solutions.
- Rate this statement: I like to use graphs to make scientific claims or figure out best design solutions.
- Rate this statement: I like to use models to make scientific claims or figure out best design solutions.
- Rate this statement: I like to use technology to make scientific claims or figure out best design solutions.
- Rate this statement: I like to use statistics and probability with digital tools to answer science and engineering questions.
- Rate this statement: I like to think about the limits of my data, such as error and sample size, and how to improve studies in the future.
- Rate this statement: I like to look for what is the same and what is different about my findings and other data.
- Rate this statement: I like to consider how new data will impact my explanations.
- Rate this statement: I like to use data to optimize design features or characteristics for success.
- Rate this statement: I like to use data to determine the relationship between variables in an experiment.
- Rate this statement: I like to make explanations considering data, models, theories, simulations, and help from peers.

- Rate this statement: I like using laboratory data, scientific ideas, principles, and evidence to explain laboratory findings, thinking about unanticipated effects.
- Rate this statement: I like to use reasoning, theories, and models to match evidence with claims to determine if an explanation has support.
- Rate this statement: I like developing realistic solutions to problems based on science ideas and evidence after considering the importance of various criteria and making tradeoffs.
- What do you think are some important practices to use when completing science laboratories?
- What is analyzing and interpreting data?
- Rate this statement: I am good at analyzing and interpreting data.
- Why is analyzing and interpreting data important?
- Share an example of how you have analyzed and interpreted data in the past.
- What is constructing explanations and designing solutions?
- Rate this statement: I am good at constructing explanations and designing solutions.
- Why is constructing explanations and designing solutions important?
- Share an example of how you have constructed explanations and designed solutions in the past.

Design

This portion of the study was a within-participants design to study thoughts about student laboratory completion within the intervention group over time.

Participants

The participants for this part of the study were the 30 intervention students from fall 2017 who received the intervention and chose to respond to the course surveys.

Data Analysis

Data analysis for this portion of the study (Table 3.6) was:

- Comparing Likert responses before and after the study. I studied quantitative responses to these questions by using a t-test of the means for statistical significance.
- Comparing open-ended comments for types and numbers of comments.

Research Question Four

Do introductions before online forensic science laboratories focused on key content, procedures, and two NGSS SEPs (analyzing and interpreting data and constructing explanations and designing solutions) promote student use of those NGSS SEPs in laboratory responses? A key interest was the quality of student use for each laboratory assignment.

Measures

There were several sources of data for this fourth question (Table 3.6) including

- Laboratory completion rates and scores for the fall 2017 (intervention) class.
    - The four simulation laboratories were pH, density, target, and projectile motion.
    - The eight at-home laboratories were soil, fingerprint, hair, drug survey, red cabbage, chromatography, DNA extraction, and blood splatter.

- Researcher designed laboratory rubric scores for the intervention class based on the focus NGSS SEPs (Appendix D). NGSS SEPs areas considered were:
    - Analyzing and interpreting data
        - Effectively uses tools, technology, and/or models to make valid and reliable scientific claims or determine optimal design solutions
        - Effectively uses statistics and probability to address scientific and engineering questions, using digital tools when feasible
        - Effectively uses limitations of data analysis when analyzing and interpreting data
        - Effectively uses comparisons and contrasts of data to examine consistency of measurements and observations in data
        - Effectively uses evaluation to determine the impact of new data on a working explanation and/or model of a proposed process or system
        - Effectively uses data analysis to determine design features or characteristics of a process or system to optimize it based on success criteria
    - Constructing explanations and designing solutions
        - Effectively uses quantitative and/or qualitative claims to explain the relationship between independent and dependent variables

    - Effectively uses a variety of valid and reliable sources to make explanations
    - Effectively uses scientific ideas, principles, and/or evidence to construct an explanation of phenomena and solve design problems, considering unanticipated effects
    - Effectively uses scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion
    - Effectively uses scientific knowledge, student-generated sources of evidence, prioritized criteria and tradeoff considerations to design, evaluate, and/or refine a solution to a complex real-world problem

- Analyzing laboratory answers for the types and number of errors in using the focus NGSS SEPs.

<u>Design</u>

To answer this research question, I used a within-participants design to study intervention student use of the focus NGSS SEPs for each laboratory.

<u>Participants</u>

The participants for this part of the study were the 30 students who received the intervention in fall 2017.

<u>Data Analysis</u>

Data analysis (Table 3.6) for the question consisted of:

- Summarizing average laboratory completion rates and report scores for each laboratory in the intervention class.
- Using rubric scores and answer analysis to identify patterns in intervention laboratory report answers.

Synthesis of Data

I identified relationships between the findings of the four research questions. I was able to make connections between the questions asked by students and the laboratory completion. There was also a relationship between student thoughts about the SEPs, their use of the SEPs, and laboratory completion.

Reliability

When completing research studies, they must be reliable. Miles, Huberman, and Saldana (2014) list several items to consider when creating a reliable research study. Reliability is making sure "the study process is consistent, reasonably stable over time and across researchers and methods" (Miles, Huberman, and Saldana ,2014, p. 312). For this project I focused on the following areas recommended by Miles, Huberman, and Saldana (2014) to add to the quality of the study:

- designing clear and consistent research questions
- articulating my role as the researcher
- expressing parallels in data with respect to study members and context over the length of the study
- sharing underlying theories
- collecting data related to the research question extensively
- checking data for bias and other ethical concerns

- having the school peer review elements

Validity

Studies must also be valid, or be truthful and have credibility (Miles, Huberman, and Saldana, 2014, p. 312). For this study I concentrated on the following ideas to increase validity:

- triangulating data with a variety of data collection
- having my work peer reviewed through the science lead teacher before adding the introductions to the master course
- analyzing negative cases
- reflecting on my biases
- adding thick descriptions of the research context

Study Considerations

I have considered the impact of the study on both students and course quality. Before the study started, I obtained IRB approval to collect data for the intervention class and use archived data from previous classes. Parental consent and student assent were a requirement for the intervention class participation. However, all students, regardless of consent or assent, had the opportunity to complete each component of the study. I assigned students randomly chosen numbers to represent them in order to protect student confidentiality. I, the teacher of record, was the researcher for the study. The intervention class had all the current components of the class as it was previously designed with the addition of the survey and NGSS SEPs introductions. Both the previous and intervention classes received the same content and instruction with the exception of the intervention class having the intervention.

Risks to students as a result of the study were minimal. The main risk was the slightly increased workload for the intervention class with the added introductions which may have caused students in that group to need more time to complete laboratory assignments. However, the goal of the intervention design was to help students complete the laboratory assignments more efficiently and with a higher degree of success. Another possible risk was students feeling uncomfortable about completing the surveys.

Limitations

There were a variety of limits impacting the study. Limitations occurred due to the lack of generalizability of the data, the design of the introductions, and the types of tools used.

Study limitations resulted from an inability to generalize findings due to the small intervention and comparison group sample sizes. The design required convenience sampling from a specific course with limited enrollment, making it difficult to determine if results would be applicable to other populations of students and to additional science topics. Furthermore, it was hard to determine what impact laboratory design or course timing had on the outcome of the study. Perhaps, with varying laboratory designs, the impacts of helping students use and understand the SEPs of the NGSS could be different.

Another constraint was the design of the introductory intervention. The introduction creation occurred in www.h5p.org (H5P, 2017). This program does not allow instructors to track the use of material produced at this site. Therefore, it is impossible to ascertain how many students interacted with the introductions and the quality of their interactions with the introductions. Furthermore, the introductions provided information about content, procedures, and NGSS SEPs. Thus, making it difficult to determine which aspects of the introductions were helpful to students.

Finally, there were no created surveys and rubrics available for the study. Therefore, I designed the pre-course and post-course survey (Appendix B & C) and the Focus NGSS SEPs Rubric (Appendix D). If pre-designed surveys and rubrics were available, they would have experienced more rigorous development procedures, making them more reliable and valid for research use. This, in turn, would have further strengthened the study results. Furthermore, providing students with the pre-survey at the beginning of the class could have encouraged students to complete the laboratories.

Significance

This study was significant as teachers look for ways to help students achieve the goals of the NGSS SEPs. It is important for instructors to implement strategies that allow students to become more interested in and better understand the SEPs of the NGSS. There is limited research on how to do this in an online science course. Pruitt (2014) supports this saying that there is much to learn about implementing the NGSS. This study provided one idea as teachers try to better incorporate the NGSS SEPs. It could also be a starting point as other researchers consider ideas related to promoting student understanding of these practices.

Chapter Summary

In conclusion, this chapter summarized the methods for this study. The study used mixed methods with both quantitative and qualitative data. This information allowed me to determine trends in the data along with student thoughts to provide more insights into this information. The next chapter will analyze the findings of these methods.

CHAPTER FOUR: FINDINGS

This chapter is a summary of the findings of the study. It presents information about the results of adding introductions before laboratories. Overall trends indicate that there were less interactions between the fall 2017 intervention students and teacher than hypothesized. The other main data trends were as follows: (1) The intervention group had increased completion rates and scores for laboratories when compared to the fall 2016 comparison group, (2) intervention students had similar interest levels in the NGSS SEPs, but showed shifts in thoughts about laboratory practices and NGSS SEPs, and (3) intervention student use of the NGSS SEPs varied with the laboratory assignment, indicating the need for continued improvements to the introductory intervention.

Question One Findings: Student-Teacher Interactions Before Laboratories

Research question one was: Do introductions before online forensic science laboratories focused on key content, procedures, and two NGSS SEPs (analyzing and interpreting data and constructing explanations and designing solutions) promote student interactions with the course instructor by students asking questions before completing the laboratories? Of interest was whether the introductions influenced the frequency of questions students asked regarding procedures, data analysis, or content. These areas were a focus because they were listed as main reasons for students asking questions before laboratories.

Teacher-intervention student communications and survey responses showed a shift in student-teacher interaction expectations and actual interactions. Before the study, most intervention students were neutral about liking help before laboratories. At the end of the study, a majority of intervention class students participating in the post-survey said that they had no questions before laboratories. If they did have questions, they were most likely procedural. Some intervention students identified the reason for their lack of questions was the clarity of the laboratory directions. Thus, showing that the introductory intervention did not promote an increase in student-teacher interactions, but provided procedural support for students. This support translated into the need to ask fewer procedural questions.

<u>Overall Neutral Responses About Help Before Laboratories</u>

The intervention students who had access to the introductory interventions and participated in the pre-survey did not have strong feelings about liking help from the teacher before laboratories at the beginning of the class. According to the intervention pre-course survey answers, 85% neither approved nor disapproved of the statement, *I like to get teacher help before starting a laboratory* (Figure 12).

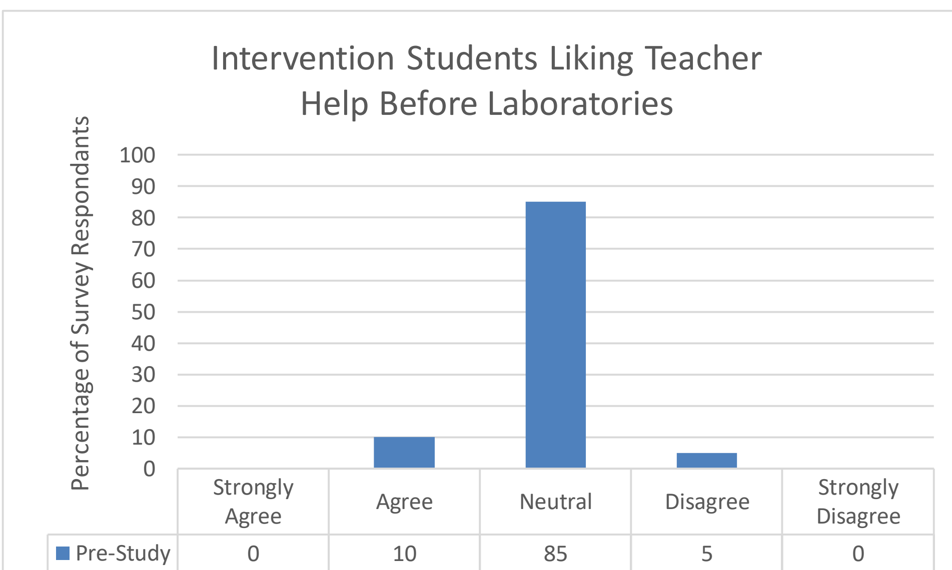


Figure 12. Intervention Students Liking Teacher Help Before Laboratories

Procedural Questions Most Common

Open-ended intervention pre-survey responses to the question, *What kind of questions do you usually have about laboratories*, provided more information about student expectations for help before laboratories. Seventy-one percent answered that their questions before laboratories would be procedural – lab steps. An exemplar answer was "What are we looking for in the lab exactly?" Another was, "When I am in a lab I usually have to double check to make sure I know what the instructions are and to make sure I'm doing the process correctly, so I don't mess up my end results." Additional open-ended pre-survey intervention student responses about questions before laboratories were 29% of intervention students answering that they normally do not have any questions at the start of laboratories. Fourteen percent shared that they had content questions. Another 14% suggested the need for procedural – technology questions. Five percent identified having procedural – materials questions.

Class emails and phone logs confirmed that there were a limited number of questions before laboratories (Figure 13). There were 32 questions in total for all 30 of the intervention students over the course of the 12 laboratories in the study (Figure 13). Only two of the 32 questions were about the four simulation laboratories, showing the hands-on laboratories led to more questions. The majority of questions were procedural (Figure 13). These procedural questions fell into the major categories of technology (31%), materials (25%), laboratory steps (19%), and time (16%). Less questions about data organization (6%) and content (3%) also occurred. At the end of the study, 53% of the intervention class students participating in the post-survey said that they had no questions before laboratories, another 29% had procedural - steps questions, 18%

mentioned procedural – materials questions, 6% discussed procedural – time questions and another 6% highlighted content.

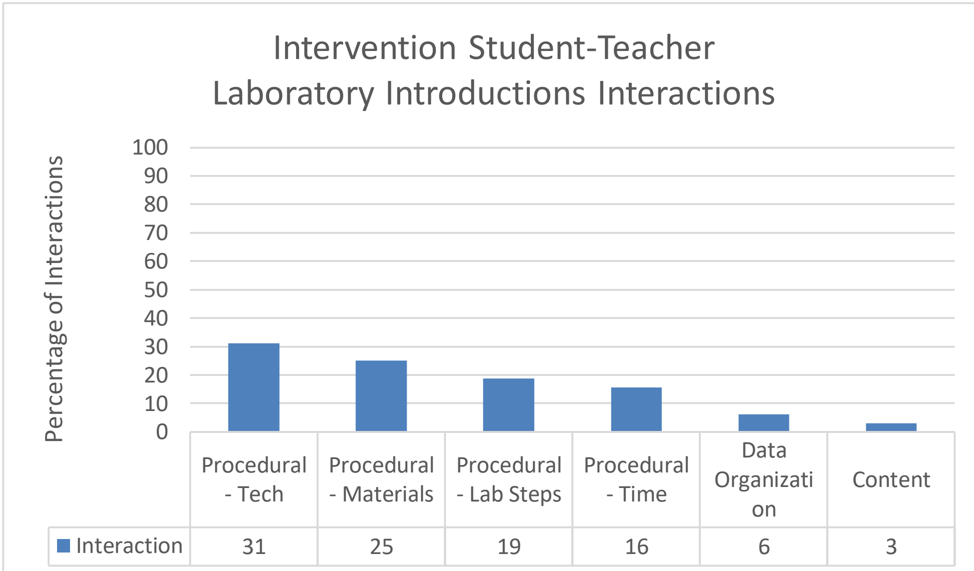


Figure 13. Intervention Student-Teacher Interactions Before Laboratories Based on Teacher Logs

Introductions Helpful

Seventy percent of post-survey intervention class respondents thought that the introductions explaining the laboratories were helpful (Figure 14). Twelve percent felt neutral about them, and 18% did not find them to be helpful. Therefore, while most students found the introductions helpful, it is possible to better survey students in the future and determine which additional supports might be more beneficial for students when completing laboratories and utilizing the NGSS SEPs. Some comments from the students were that they did not have questions about the laboratories and that the laboratories were self-explanatory. Others included, “Your labs are usually pretty straight forward” and “The video for the last lab that we did was very helpful, and it was easy to understand.”

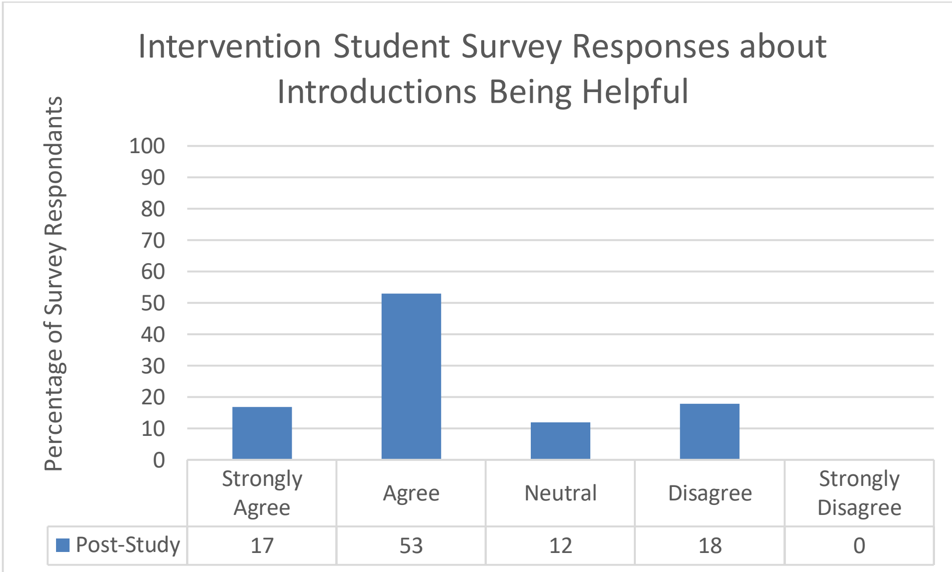


Figure 14. Intervention Student Survey Responses about Introductions Being Helpful

Question Two Findings: Laboratory Completion Rates

The second research question for this study was: Do introductions before online forensic science laboratories focused on key content, procedures, and two NGSS SEPs (analyzing and interpreting data and constructing explanations and designing solutions) promote student completion of those laboratories? Of specific interest was whether the introductions influenced intervention student (fall 2017) laboratory completion and laboratory scores when compared to the control class (fall 2016). Another concern was if there was a difference in completion rates for simulation and at-home laboratories for intervention (fall 2017) students. Since the structure of these two types of laboratories were so different, it was beneficial to look at student completion for each with and without the introductions.

There was an increase in laboratory completion rates for both simulation and at-home laboratories between the comparison and intervention class. The results illustrated that both the comparison and intervention students completed the simulation laboratories more often than the at-home laboratories. However, the laboratories presented some barriers to students enjoying the online science format, including issues with getting materials and having enough time for laboratory completion.

High Intervention Student Expectations About Completing Laboratories

Intervention students started the class with high expectations about working through all the laboratories. At the beginning of the intervention class, 90% of the intervention students strongly agreed or agreed with this statement, *I am planning to complete all the laboratories for this class* (Figure 15). In open-ended follow-up pre-survey responses, intervention students shared reasons for why they might not complete a laboratory. These were: they might not understand (38%), run out of time (38%), forget (10%), have technical issues (10%), or lack materials (10%). Some exemplar statements about not completing laboratories were, “If it was really hard or made no sense.”, “If I am running out of time to finish a class and I don’t have time and it’s not worth a lot of points.”, “I forget about it.”, “If my school computer won’t connect to the Internet at home.”, and “If I don’t have the materials to do so.” Alternatively, 19% of students said they would never skip a laboratory assignment. One response was, “I would not skip a laboratory assignment because grades are extremely important to me.”

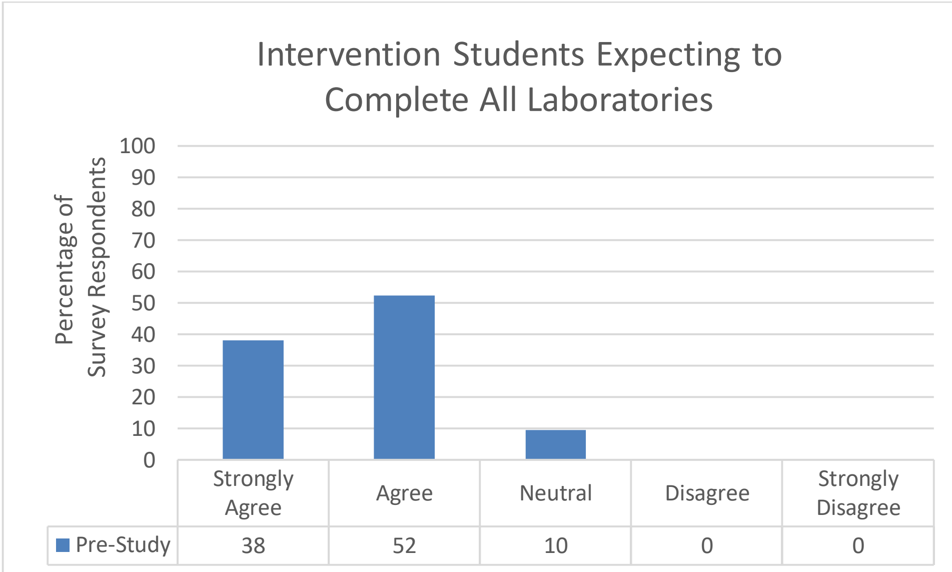


Figure 15. Intervention Students Expecting to Complete All Laboratories

Higher Levels of Simulation Laboratory Completion

There were four simulation laboratories for the class, pH, density, target, and projectile motion. Most (67%) of the intervention class students completed all four of these laboratories, 16% completed three of these laboratories, the rest (17%) completed two or less of these laboratories (Figure 16).

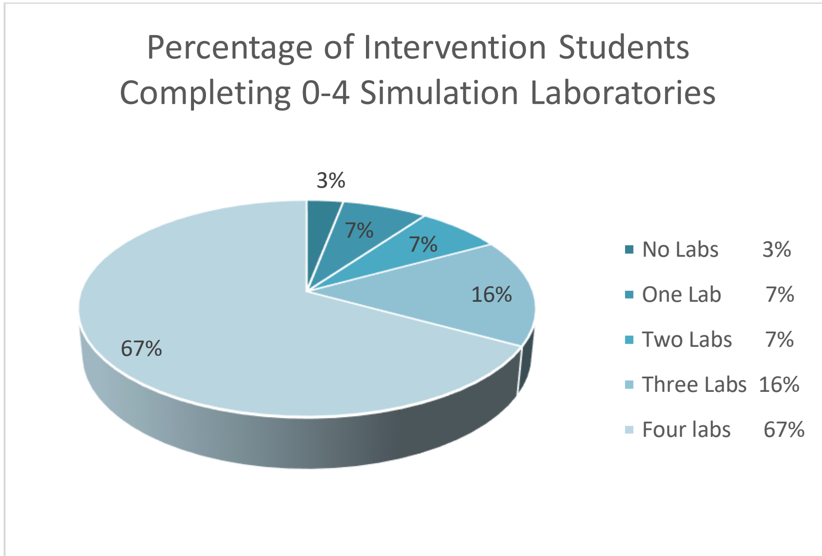


Figure 16. Percentage of Intervention Students Completing 0-4 Simulation Laboratories

An analysis occurred between the comparison class completion rates and the intervention class completion rates for the simulation laboratories (Figure 17). The data indicated that a slightly higher percentage of students in the fall 2017 intervention class completed the simulation laboratories. Students also scored slightly better on the simulation laboratories in the fall of 2017 (Figure 18). However, the mean scores for the intervention class when measured against the comparison class for all the simulation laboratories (including students who did not complete the laboratories) were not significantly different based on t-tests of the means for all the laboratories from the two groups (Table 4.1).

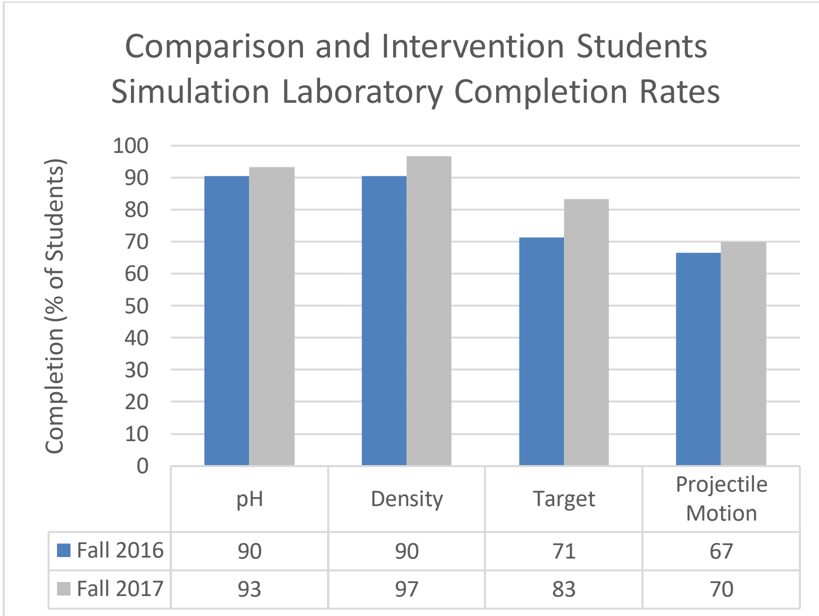


Figure 17. Comparison and Intervention Simulation Laboratory Completion

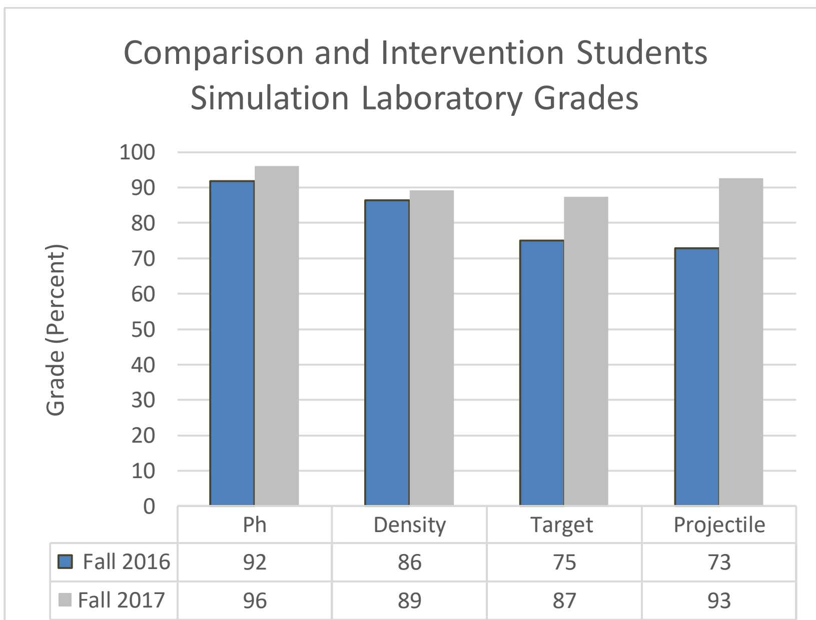


Figure 18. Comparison and Intervention Students Simulation Laboratory Grades

Table 4.1 T-test Results for the Means of All Simulation Laboratory Grades Between the Intervention and Comparison Classes

Laboratory	Fall 2016 Mean Scores (Out of 24)	Std Deviation	Fall 2017 Mean Scores (Out of 24)	Std Deviation	t	p
Ph	19.9286	6.73291	21.5333	6.05995	0.873	0.388
Density	18.7619	7.39023	20.70000	4.77168	1.057	0.298
Target	12.8571	9.05696	16.7667	8.83931	1.532	0.133
Projectile Motion	11.6667	9.52409	15.6500	10.55540	1.405	0.167

Lower Levels of At-Home Laboratory Completion

There were eight at-home laboratories for the class: soil, fingerprint, hair, drug survey, red cabbage pH, chromatography, DNA extraction, and blood splatter. Thirty percent of fall 2017 intervention class students completed all eight of these laboratories, while 10% did not complete any of these laboratories (Figure 19).

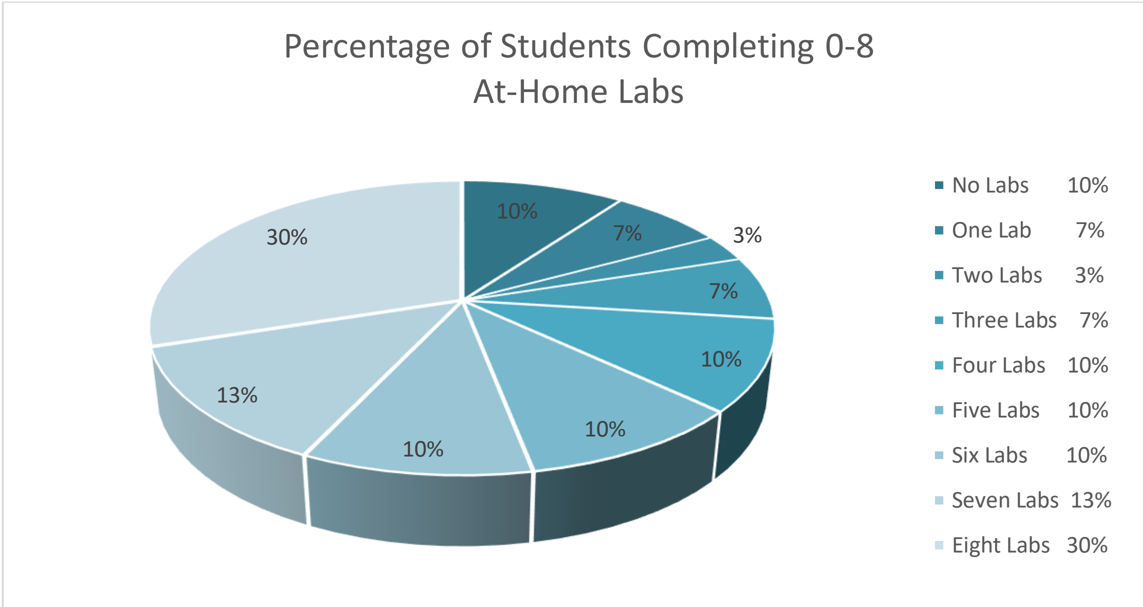
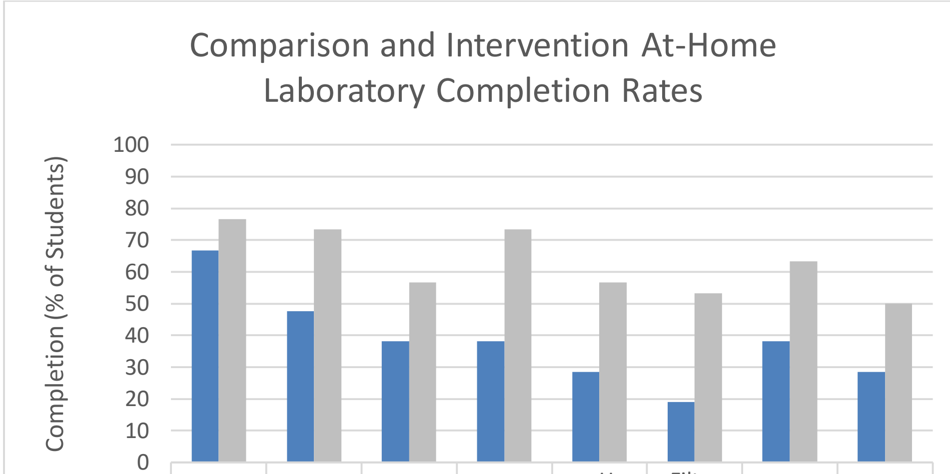


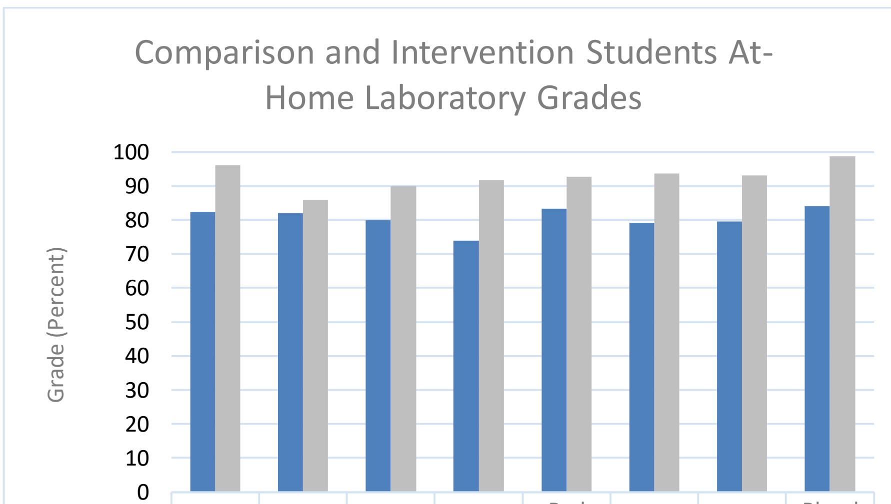
Figure 19. Percentage of Intervention Students Completing 0-8 At-Home Labs

An analysis occurred between the comparison and intervention class completion rates for the at-home laboratories (Figure 20). The data showed that a higher percentage of students in the intervention class completed the at-home laboratories. Students also scored slightly better on the at-home laboratories during the fall 2017 intervention class when compared to the fall 2016 comparison class (Figure 21). Some laboratories (drug survey, red cabbage, chromatography, DNA extraction, and blood splatter) showed significant differences for the total mean scores based on t-test results ($p < 0.05$). Some other at-home laboratories (soil, fingerprint, and hair) did not show significant differences in means (Table 4.2). Perhaps the introductions had more of an impact on encouraging students to participate successfully in the later laboratories for the course or helped students understand them better.



	Soil	Fingerprint	Hair	Drug Survey	pH Cabbage	Filter Paper Chromo	DNA	Blood Splatter
Fall 2016	67	48	38	38	29	19	38	29
Fall 1017	77	73	57	73	57	53	63	50

Figure 20. Comparison and Intervention Students At-Home Laboratory Completion



	Soil	Finger print	Hair	Drug	Red Cabbage	Chromo	DNA	Blood Splatter
Fall 2016	82	82	80	74	83	79	80	84
Fall 2017	96	86	90	92	93	94	93	99

Figure 21. Comparison and Intervention Students At-Home Laboratory Grades

Table 4.2 T-test Results for the Means of All At-Home Laboratory Grades Between the Intervention and Comparison Classes

Laboratory	Fall 2016 Mean Scores (Out of 24, except DNA Extraction Out of 15)	Std Deviation	Fall 2017 Mean Scores (Out of 24, except DNA Extraction Out of 15)	Std Deviation	t	p
Soil	13.1667	10.85511	17.6667	10.11429	1.498	0.142
Fingerprint	9.3571	10.63854	15.1333	10.16326	1.944	0.059
Hair	7.3095	10.52672	13.0167	11.28203	1.850	0.071
Drug Survey	6.7619	9.05486	16.1333	10.20390	3.451	0.001
Red Cabbage	5.7143	9.36559	12.6000	11.28349	2.295	0.026
Chromatography	3.6190	7.88972	12.3333	11.84769	2.941	0.005
DNA Extraction	4.5476	6.14798	8.3667	6.994499	2.015	0.049
Blood Splatter	5.7619	9.85852	12.6333	12.02722	2.158	0.036

Reasons for Non-Completion

Only 62% of intervention students expected to enjoy studying science in an online format before the study. Intervention students recognized both advantages and disadvantages to studying science online in the pre-class survey. Many comments (40%) discussed advantages, such as you can work at your own pace, have flexibility, and do the classwork on your own time. Another advantage, which was acknowledged by 30% of students, was having online resources available for help. Students perceived the disadvantages of online science classes as missing hands-on opportunities (60%), the lack of interaction with a teacher (40%), and procrastination due to flexible schedules (5%).

One exemplar comment was, “You can work at your pace, but then again you don’t have the interaction of the teacher in person if you get stuck.” Another was, “Some disadvantages about studying science online is that you do not get real hands on learning and if you need help with something the teacher might not be available to help you in person.” One student stated that an advantage was having “the Internet as a resource in case you are unsure about a topic.”

Intervention students did not like studying science online as much as they thought they would. After the intervention class, 41% actually agreed or strongly agreed they liked studying science online and 41% were neutral. The percentage of intervention students disagreeing about liking science online jumped to 18%. The disadvantages of studying science online were students missed face-to-face interactions (47%), had trouble getting materials (24%), and thought online laboratories were difficult to understand (6%). Flexibility was still an advantage to 35% of students. Resources were also helpful for 24%.

Furthermore, for the class in general, students did enjoy the new content (53%), appreciated the real life/career aspects (29%), but thought that the class and/or laboratories were too much work (35%). One even expressed wanting more activities and not laboratories. Six percent liked the course resources. Six percent also struggled with procrastination due to flexibility. One example of what a student said about the class was “I really liked this class a lot! Science hasn’t been a favorite class of mine so being able to apply it to something I’m interested in really helped me learn some parts of science better.” Another was “I loved the class, I just disliked the labs.” Not liking the online laboratories could have been a contributor to students not liking the online science format as much as they had anticipated.

In addition to having high expectations about online science, intervention students also expressed some enthusiasm about online laboratories (Figure 22). The majority of students, 80%, agreed or strongly agreed that they would like simulation laboratories. Only 50% agreed or strongly agreed that they would like the at-home laboratories. What the intervention students had historically appreciated about completing laboratories included having hands-on experiences (71%) and learning new information (65%). However, one student saw hands-on experiences as negative.

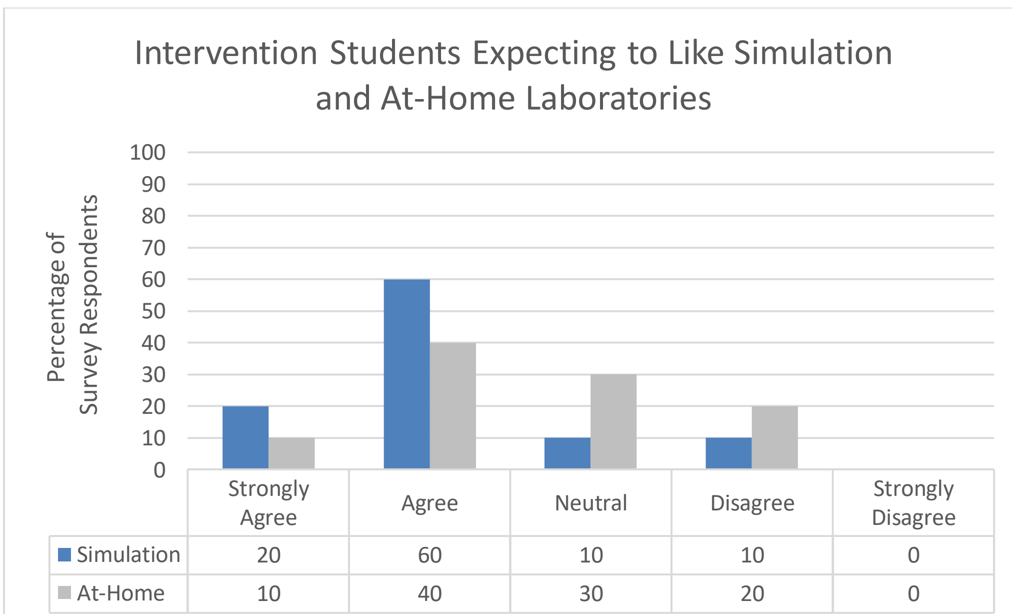


Figure 22. Intervention Student Expectations About Liking Simulation and At-Home Laboratories

Despite these positive expectations, intervention post-course survey results revealed that the intervention students did not like simulation or at-home laboratories as much as they thought they might (Figures 23 & 24). While 80% of the intervention class pre-survey participants expected to like simulation laboratories, only 64% agreed or strongly agreed that they liked the simulation laboratories at the end of the course. On the other hand, 50% of the intervention pre-survey participants expected to like the at-home laboratories, but only 41% of intervention post-survey participants did. Furthermore, 35% of the intervention post-survey participants strongly disagreed about liking the at-home laboratories. This lack of interest in the hands-on laboratories could have led to the simulation laboratories being completed more.

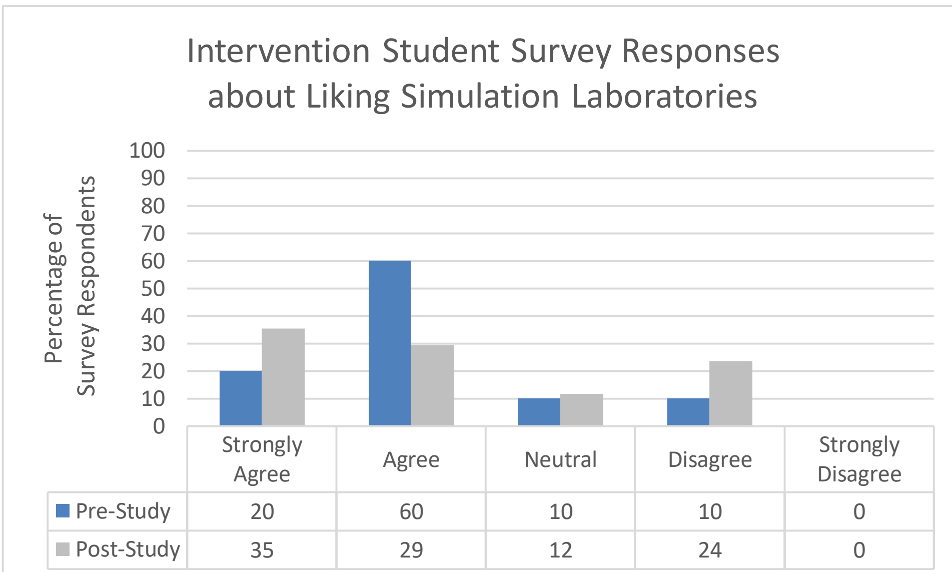


Figure 23. Student Pre- and Post-Survey Responses About Liking Simulation Laboratories

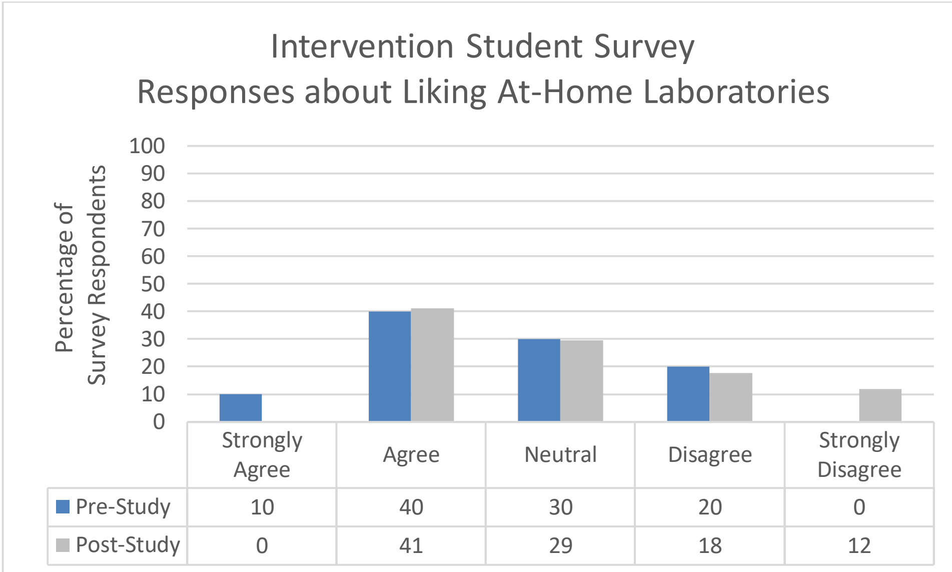


Figure 24. Student Pre- and Post-Survey Responses about Liking At-Home Laboratories

Student answers about why they skipped a laboratory assignment were mainly due to lack of materials (41%), time (41%), and difficulty completing or not wanting to expend the required excess mental work (12%). Exemplar comments were “I didn’t have some of the materials and wasn’t going to waste money to get that one thing.” and “Didn’t have enough time to do them.” Twenty-four percent of the intervention students answering the post-survey said that they did not skip a laboratory assignment. Perhaps, this shows that students better understood the laboratory procedures due to the introductions, but the introductions failed to address other factors vital to completion, such as materials and time.

Although students highlighted some important reasons why they would not do a laboratory for the class, some students responded positively to the question, *What did you like best about the laboratories*, in the post-course survey. Forty-one percent of the students said they liked learning content from the laboratories in the class. For example, “It was fun to do them and learn how things would work in forensic science.” Another

41% appreciated the “hands-on” experiences. Eighteen percent did not like the laboratories or only liked the laboratories once they were completed. One student brought up that “I liked that I got to involve my brother in some of the at-home labs.”

Overall, intervention student self-ratings of expectations about completing laboratories (4.29 with a standard deviation of 0.644) were higher than student self-ratings on actual laboratory completion (2.82 with a standard deviation of 1.425) (Figure 25). This difference in means was significant based on a t-test ($t = 4.212$, $p = 0 .000$). Expectations about completing the laboratories had a rubric score of 4.29, which is an average between agreeing and strongly agreeing. Actual student thoughts about their laboratory completion had a rubric score of 2.82, which is an average between neutral and disagreeing.

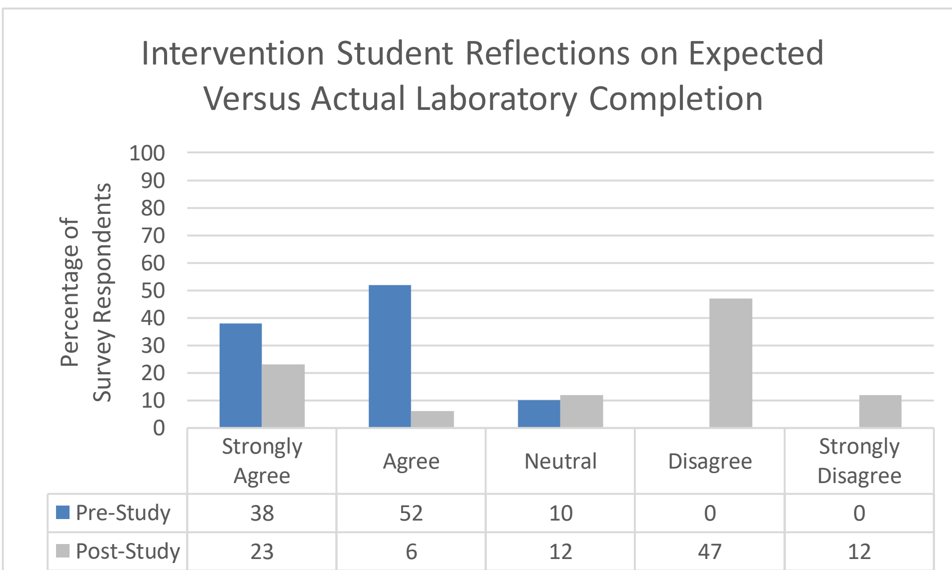


Figure 25. Intervention Student Pre- and Post-Survey Responses About Laboratory Completion

Relationship Between Interactions and Completion

The study findings indicated that even though there was no increase in intervention student-teacher interactions because of the introductions, laboratory completion rates for both the intervention simulation and at-home laboratories increased. The introductions presented students some information related to procedure, content, and NGSS SEPs. This allowed students to understand the procedures, content, and laboratory practices related to each laboratory, thus leading students to need less interactions with the instructor related to the laboratories. However, the findings indicate that other factors, such as time, materials, and thinking, did contribute to student non-completion of laboratories. Therefore, exploring other ways to help students reduce the obstacles of online laboratories could be helpful to increasing both student-teacher interactions and online laboratory completion.

Question Three Findings: Shifts in Student Thoughts

The third research question for this study was: Do introductions before online forensic science laboratories focused on key content, procedures, and two NGSS SEPs (analyzing and interpreting data and constructing explanations and designing solutions) promote student thinking about the NGSS SEPs? Of main concern was what the shifts in thinking were. These areas can be good indicators of student engagement with the NGSS SEPs.

There were shifts in student thinking related to online science and the NGSS SEPs. Possible shifts were considered related to student interest in the focus NGSS SEPs, laboratory practices in general, and thoughts about the focus NGSS SEPs. Shifts were not seen in interest related to the focus NGSS SEPs. However, there were changes in actual thoughts about the laboratory practices and the focus NGSS SEPs

No Changes in Focus NGSS SEPs Interest

Despite not liking the online science laboratories as much as they had hoped, students showed similar levels of interest in the components of the SEPs of focus for the study (Table 4.3). Their interest in the SEPs did not change from the pre- to post-study survey. Students also showed similar levels of interest across SEPs, and there was no significant differences in any means. Ratings for each interest statement averaged between three (neutral) and four (agreeing).

Table 4.3 Intervention Class Pre- and Post-Survey Student Interest in SEPs

NGSS SEP	Fall 2016 Mean Scores (Out of 3)	Std Deviation	Fall 2017 Mean Scores (Out of 3)	Std Deviation	t	p
Tables	3.43	0.926	3.24	1.033	0.601	0.552
Graphs	3.19	0.928	3.19	1.223	0.008	0.994
Models	3.52	0.814	3.41	1.004	0.372	0.713
Technology	3.43	0.746	3.71	0.985	0.959	0.345
Statistics	3.33	0.913	3.29	0.849	0.137	0.892
Data Limits	3.33	0.796	3.35	1.057	0.063	0.950
Data Differences	3.67	0.730	3.59	0.795	0.313	0.756
New Data	3.52	0.750	3.47	0.800	0.210	0.835

(table continues)

Table 4.3 continued

NGSS SEP	Fall 2016 Mean Scores (Out of 3)	Std Deviation	Fall 2017 Mean Scores (Out of 3)	Std Deviation	t	p
Optimization	3.43	0.676	3.47	0.943	0.154	0.878
Relationships	3.43	0.746	3.53	0.800	0.398	0.693
Explanations	3.33	0.796	3.41	0.939	0.274	0.786
Unanticipated Effects	3.48	0.873	3.47	0.943	0.019	0.985
Reasoning	3.65	0.587	3.63	0.885	0.097	0.923
Realistic	3.38	0.740	3.63	0.885	0.891	0.380

Shifts in Laboratory Practices Thinking

At the beginning of the class, many of the intervention students, 71%, were concerned with procedural steps such as safety, testing more than once, being consistent, how to use certain things, proper information gathering, and step completion. This was followed by data (48%), which included comments about going over data, comparing data, recording all data, being precise, and using data to express points. Understanding content and what was happening was also important to 10% of pre-survey respondents.

Intervention post-survey results identifying practices were similar with some differences. Forty-one percent of students were still focused on procedural steps, such as following directions and safety. Data was another large focus (35%), including writing data down, being accurate, observing, and analyzing data. Of bigger concern at the end of the study was content understanding (24%), having the proper materials (12%), and working on the labs over time (6%). Perhaps there was a shift towards an awareness about supplies and time because those were the biggest obstacles acknowledged by students when discussing laboratory completion.

<u>Shifts in Focus NGSS SEPs Thinking</u>

Intervention survey results showed students perceived a small change in their thoughts about being able to analyze and interpret data and a larger shift for constructing explanations and designing solutions (Figure 26). Pre-survey students had an average mean self-rating of 3.60 (between neutral and agreeing) for the statement, *I am good at analyzing and interpreting data*, and standard deviation of 0.681. By the end of the class, students gave themselves slightly higher scores about their ability to analyze and interpret data (average mean of 3.71 and standard deviation of 0.849). However, these results were not significant ($t = 0.414$, $p = 0.682$).

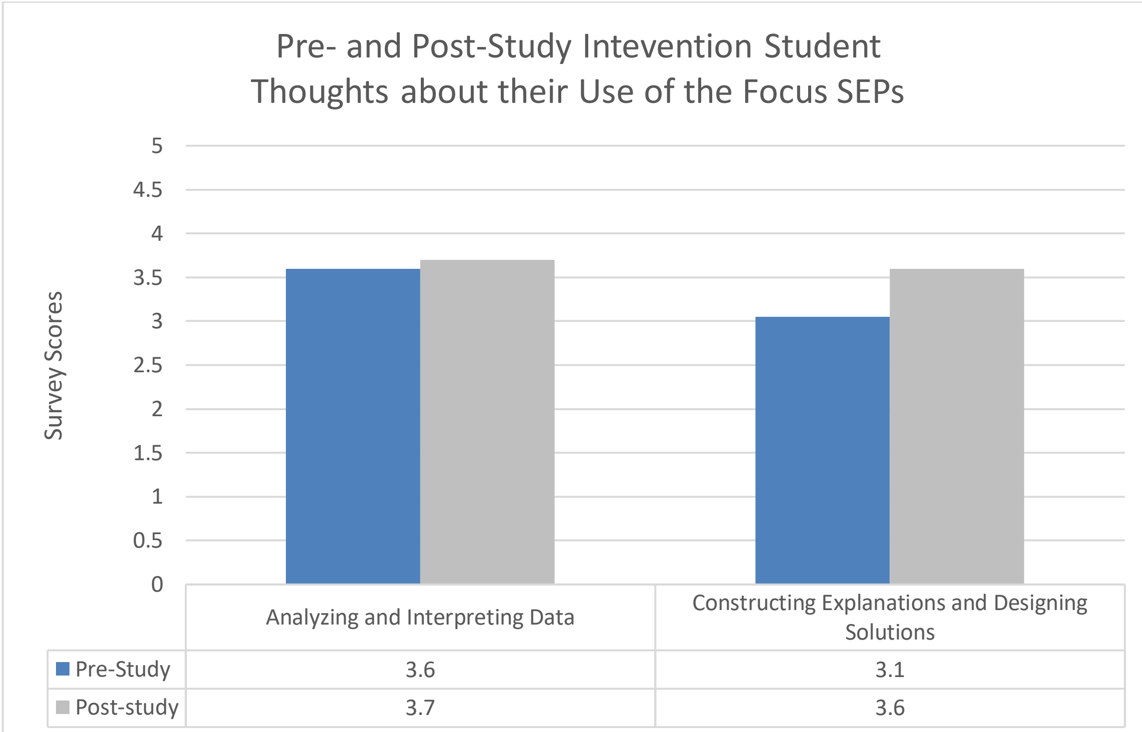


Figure 26. Pre- and Post-Survey Scores for Intervention Student Thoughts About Their Use of the Focus NGSS SEPs

The open-ended survey questions about analyzing and interpreting data also yielded a shift in thinking. In the pre-study survey, all students expressed that analyzing and interpreting data helped one study, understand, look at, and see what data means. Ten percent discussed application such as “applying new data and information” and looking at the meaning of similarities and differences. At the end of the study, all students again expressed the importance of data analysis to study, understand, and see data. However, 41% also saw analyzing and interpreting data as applying data to areas such as “finding a way to put it into the problem,” “applying your information,” “finding patterns and similarities,” and seeing “how you would put that information to use in the real world.”

As for the importance of analyzing and interpreting data, 52% of intervention pre-survey respondents wrote about knowing and understanding data. Fifty-two percent of responses also acknowledged the importance of making information available in a usable format to others, proving a hypothesis, or making conclusions. After the study, post-survey intervention results showed 65% of students expressing that data analysis and interpretation was instrumental in better understanding results. Another 71% acknowledged needing to apply data to achieve the next steps such as finding a conclusion, comprehending a problem, accessing information later, explaining it to others, making good conclusions, comparing and contrasting, seeing the meaning behind the information, and making "progress in the world we live in and fix mistakes in the past." This demonstrated a shift in thinking towards greater levels of the application of the data sets collected in science.

Intervention student recognition of their use of analyzing and interpreting data showed some shifts in student thinking. Sixty-one percent of the pre-survey respondents discussed going over tables and graphs to see information. For example, "I once had to take data from a table and convert it to a line graph." Another 43% were able to express how data analysis and interpretation helped them to discover new ideas. One student described a water quality activity this way, "Because we analyzed our data we were able to back up our information and give good reasoning for why the water quality was worse in the developed areas." Another 19% did not provide an answer to the question about how they have analyzed and interpreted data in the past. Post-study intervention respondents differed in the fact that no students left the question unanswered, 71% of students shared how they analyzed graphs and charts to understand data, and 76% articulated how they were able to use this information to compare and gain insights. Interestingly, some students shared examples of how they used analyzing and interpreting data outside of laboratory assignments. For instance, two students expressed how they analyzed and interpreted data while completing the criminal case assignments for the course. One said, “After reading up on the criminal case, I would have to analyze all of my collected data and put it into a summary using my interpretation of the findings.”

Pre-survey students had an average mean self-rating of 3.05 (between neutral and agreeing) for the statement, *I am good at constructing explanations and designing solutions*, and standard deviation of 0.887 (Figure 26). By the end of the class, students gave themselves higher scores in this area (average mean of 3.59 and standard deviation of 0.721). The results were significant ($t = 2.046$. $p = 0.048$). Perhaps discussing these in the introductions allowed students to better recognize their abilities in these areas.

When considering what constructing explanations and designing solutions were, 33% of the pre-survey intervention students were unable to answer the question or answered they did not know. The remaining 67% were able to identify this practice as an important step in determining a solution, thinking critically, a process of problem identifying and testing, explaining studies, applying what you learn, using equations, and/or helping further an idea. All of the post-survey intervention students were able to identify how constructing explanations and designing solutions help answer questions and solve problems. There seemed to be a shift in thinking towards a better understanding of what constructing explanations and designing solutions are.

Correspondingly, 33% of intervention students taking the pre-survey could not answer why constructing and designing solutions were important. Sixty-seven percent of students answered the question. Some aspects stressed by 57% of students were its importance in helping answer a hypothesis, solve problems, learn, know what to do, or real-life applications. Another 14% stressed understanding. At the end of the study all students were able to answer this question. Eighty-eight percent of intervention student responses included answering a question, fixing problems, knowing what happened, making a solution, making new findings, thinking in depth, explaining, and/or making experiments worth-while. Twelve percent highlighted understanding.

There was also a shift in student recognition about their use of constructing explanations and designing solutions. At the beginning of the study, 52% of pre-study intervention survey respondents did not share a way they had constructed explanations and designed solutions in the past. Ten percent discussed how they used these practices to answer questions. Another 38% discussed using the practice to make conclusions and explain why something happened. For example, “In robotics I have used this a lot when we run into a problem with our design we sit down and discuss how we can fix it, then we come up with a plan, execute it, and record it in our notebook so others can see what we’ve done.” At the end of the study, 12% did not provide an example of how they had constructed explanations and designed solutions. Six percent responded that the practice was used to answer questions or because this was what was done on labs. The remaining 82% discussed how the practice could be used to describe more specific solutions and explanations. One student said, “I constructed an explanation when we performed our milk and food dye experiment. I tried thinking of a reasonable answer as to why the food dye would move through the milk, and I designed a solution to make the food dye move faster as well as not move at all.”

Question Four Findings: Use of the Focus NGSS SEPs

Do introductions before online forensic science laboratories focused on key content, procedures, and two NGSS SEPs (analyzing and interpreting data and constructing explanations and designing solutions) promote student use of those NGSS SEPs in laboratory responses? A key interest was the quality of student use for each laboratory assignment. This was chosen to better understand if there were any trends in NGSS SEPs use over time or by laboratory.

Each laboratory focused on various parts of the two focus NGSS SEPs (analyzing and interpreting data and constructing explanations and designing solutions). Student use of the SEPs depended on the laboratory. However, I could determine areas for each laboratory where students struggled. There were no trends in NGSS SEPs use over time, as student use was very dependent on the objectives of the laboratory. Perhaps the introductions could be strengthened and/or targeted in the feedback to students to help them better use the SEPs during laboratory reporting.

There is a complete description of the rubric used in Appendix D. The tables in this section summarize the SEP and provide the average score (out of 3) for the study students who completed the laboratory.

<u>Simulation pH Laboratory NGSS SEP Use</u>

Most intervention students achieved proficiency on this introductory laboratory. The objective of the assignment was to determine the pH of substances and what happens to the pH when it is diluted with water. This laboratory had an overall completion rate of 93% and an average laboratory score of 96%. Below is a screenshot of the first page of this introduction (Picture 1). There are screenshots of and a link to the complete introduction in Appendix A.

Picture 1. Screenshot from the pH Lab Introduction

Analyzing and interpreting data rubric scores showed where intervention students had difficulties (Table 4.4). The average rubric score earned for including correctly designed tables was 2.64. One student did not add a table. Seven other students who did not earn full credit recorded at least one pH value wrong. Students completing the table were able to use the table format to present their data in a clear (average score 2.96) and organized way with the use of technology (average score 2.93). Errors in making valid and scientific claims occurred with the work of two students (average score of 2.86). Most students made valid and scientific claims about which substances were acids and bases. They also articulated what happened to the pH during the experiment.

Table 4.4 Analyzing and Interpreting Data Scores from the NGSS SEPs Rubric for the pH Laboratory

Analyzing and Interpreting Data SEPs for the Simulation pH Laboratory	Average Score (out of 3)
Includes correctly designed tables	2.64
Data analysis uses technology correctly when asked	2.96
Data display is clear	2.93
Claims are valid and scientific	2.86

Minor errors analyzing and interpreting data did not lead to significant problems in constructing explanations and designing solutions (Table 4.5). Most intervention students were able to clearly articulate the relationship between pH and substance classification as an acid or a base. They could also explain the impact of water on acids and bases. Students explained the relationships between variables (average score 2.75) using available quantitative and qualitative claims (average score 2.79). Seven students made errors in this section by not explaining all the relationships or describing them incorrectly. Issues with making explanations centered around determining if the hypothesis was true or false, clearly explaining what bases were, and describing what happens to acids and bases when water is added. Students should have correctly used their investigation (average score of 2.75) and ideas from theories and laws (average score 2.71) to make their explanations.

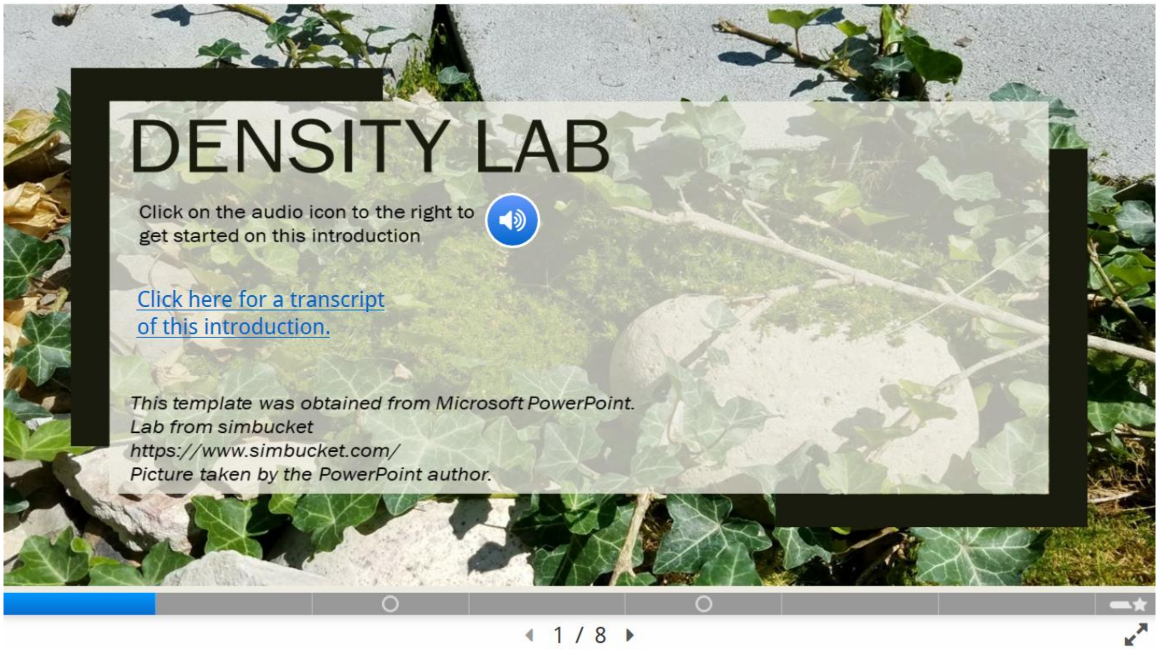
Table 4.5 Constructing Explanations and Designing Solutions Scores from the NGSS SEPs Rubric for the pH Laboratory

Constructing Explanations and Designing Solutions SEPs for the Simulation pH Laboratory	Average Score (out of 3)
Correctly and appropriately uses all available quantitative and/or qualitative claims	2.79
Clearly and correctly explains the relationship between independent and dependent variables	2.75
Uses student investigations, theories, and simulations as appropriate to make explanations	2.75
Correctly uses ideas from theories and laws to make clear explanations	2.71

One way to strengthen this laboratory is to provide individual feedback to students so that they can correct their table errors and further think about how better to explain the concepts. Materials were not an issue as it was a simulation laboratory. The high rate of completion might also show that it did not require an extensive amount of time or be related to its placement as the first laboratory in the course.

Simulation Density Laboratory NGSS SEP Use

The density laboratory also had a high rate of completion (97%). Intervention students mastered some aspects of this laboratory but struggled with others. The objective of the laboratory was to determine the mass and volume of the objects given and then use this information to determine their density. The average grade for this laboratory was 89%, which was lower than the first laboratory. Below is a screenshot of the first page of this introduction (Picture 2).



Picture 2. Screenshot from the Density Lab Introduction

When filling in the table, 12 students had trouble obtaining the volume of the floating objects and another ten had other density calculation errors (Table 4.6). The average score on the table portion of the data analysis was 1.52. Floating objects had to be completely submerged in water in order to determine the volume of the object and water. While I explained this in the introductory video, it was still unclear to some students. Some possibilities would be to remake the video and have this be of greater emphasis, present the video as an announcement when students are completing the laboratory or as feedback, or offer specific online tutoring on the topic. Due to errors in using technology, the average technology use score was 2.34. Data display was clear (average score of 3). Claims were valid and scientific with most errors in making claims about the relationship between mass and volume (average score of 2.62). Ten students had errors in this area.

Table 4.6 Analyzing and Interpreting Data Scores from the NGSS SEPs Rubric for the Density Laboratory

Analyzing and Interpreting Data SEPs for the Density Simulation Laboratory	Average Score (out of 3)
Includes correctly designed tables	1.52
Data analysis uses technology correctly when asked	2.34
Data display is clear	3
Claims are valid and scientific	2.62

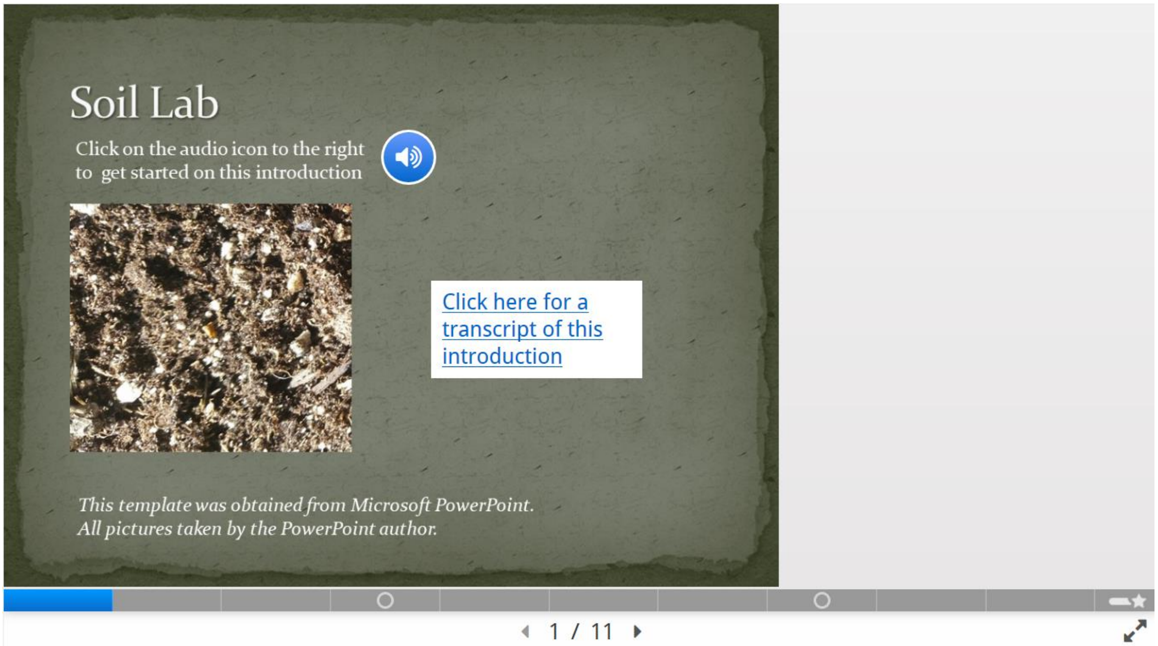
Determining the volume and density for the floating objects was difficult for some students while others had errors in calculating density (Table 4.7). Many intervention students were able to explain the use of quantitative and qualitative data (average score 2.76) to show the relationships between all the variables (average score 2.72). They were also able to make explanations from investigations, theories, and simulations (average score 2.72) and correctly use ideas from theories and laws (average score 2.76). One student disproved a true hypothesis by incorrectly obtaining the volume for the floating objects. Four did not explain how mass and volume relate to make objects float or had two substances with the same density. One did not finish the laboratory.

Table 4.7 Constructing Explanations and Designing Solutions Scores from the NGSS SEPs Rubric for the Density Laboratory

Constructing Explanations and Designing Solutions SEPs for the Simulation Density Laboratory	Average Score (out of 3)
Correctly and appropriately uses all available quantitative and/or qualitative claims	2.76
Clearly and correctly explains the relationship between independent and dependent variables	2.72
Uses student investigations, theories, and simulations as appropriate to make explanations	2.72
Correctly uses ideas from theories and laws to make clear explanations	2.76

At-Home Soil Laboratory NGSS SEP Use

Seventy-seven percent of intervention students completed the soil laboratory with an average report score of 96%. The goal of this assignment was for students to describe and compare soil samples and shoe imprints. The materials were readily available to students if the ground outside was not frozen. Therefore, the key to increasing the completion rate for this laboratory could be to remind students of the importance of doing the laboratory while the weather is good. Below is a screenshot of the first page of this introduction (Picture 3).



Picture 3. Screenshot from the Soil Lab Introduction

There were some key issues with analyzing and interpreting data (Table 4.8). For this assignment, one student did not use technology to add pictures (average technology score 2.87), and four students did not write descriptions with the pictures (average clarity score 2.57). Despite not clearly articulating their descriptions or adding pictures, students used comparisons of the samples and information about each to clearly write up valid and scientific claims (average score 3).

Table 4.8 Analyzing and Interpreting Data Scores from the NGSS SEPs Rubric for the Soil Laboratory

Analyzing and Interpreting Data SEPs for the At-home Soil Laboratory	Average Score (out of 3)
Data analysis uses technology correctly when asked	2.87
Data display is clear	2.57
Claims are valid and scientific	3

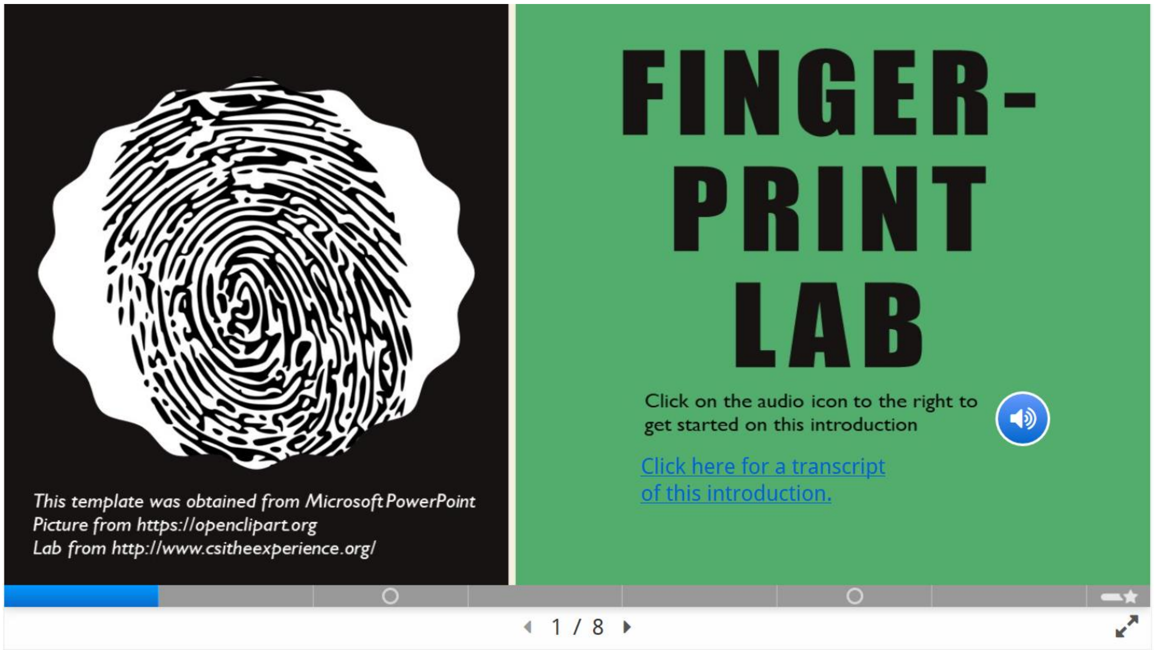
Even if lacking pictures and/or descriptions, all students were able to use the data from the laboratory to explain why soil is so important in forensics (Table 4.9). They could also make explanations and link the evidence to their claims (average scores of 3), use scientific reasoning and data (average score 3), and apply it to real-life solutions (average score 3).

Table 4.9 Constructing Explanations and Designing Solutions Scores from the NGSS SEPs Rubric for the Soil Laboratory

Constructing Explanations and Designing Solutions SEPs for the At-home Soil Laboratory	Average Score (out of 3)
Uses student investigations, models, and theories as appropriate to make explanations	3
Correctly uses ideas from theories and laws to make clear explanations	3
Correctly and clearly uses scientific reasoning, theory, and/or models as applicable to link evidence to the claims	3
Correctly assesses the extent to which the reasoning and data support the explanation or conclusion	3
Correctly uses scientific knowledge, student-generated sources of evidence, prioritized criteria and tradeoff considerations to design, evaluate, and/or refine a solution to a complex real-world problem	3

At-Home Fingerprint Laboratory NGSS SEP Use

This laboratory gave intervention students the opportunity to look at fingerprint samples. Students had the most difficulty making the graph for this analysis of data. However, the 73% of students who completed the laboratory scored an average of 86%. This laboratory required balloons and being able to adequately see fingerprints. One idea for improvement in the future includes writing alternative procedures to help students who cannot get the supplies or see the fingerprints using the provided instructions. Below is a screenshot of the first page of this introduction (Picture 4).



Picture 4. Screenshot from the Fingerprint Lab Introduction

Analyzing and interpreting data had some common errors (Table 4.10). Five students did not add a graph, and another five did not label all parts of the graph. Therefore, the average scores were 2.05 for graphing, 2.55 for technology, and 2.36 for clarity. Students were still able to arrive at valid and scientific claims (average score 2.86). One laboratory was incomplete. Students discussed the required statistics (average score 2.91), or the fingerprint with the highest number of occurrences. One student incorrectly compared the fingerprint numbers to those in the general population (average score 2.73). Making the video about the graph available alone in the announcements could help more students have the resources they need to complete the laboratory better.

Table 4.10 Analyzing and Interpreting Data Scores from the NGSS SEPs Rubric for the Fingerprint Laboratory

Analyzing and Interpreting Data SEPs for the At-home Fingerprint Laboratory	Average Score (out of 3)
Includes correctly designed tables, graphs, a model	2.05
Data analysis uses technology correctly when asked	2.55
Data display is clear	2.36
Claims are valid and scientific	2.86
Effectively uses statistics and probability to address scientific and engineering questions, using digital tools when feasible	2.91
Correctly considers sample selection when applicable	2.73

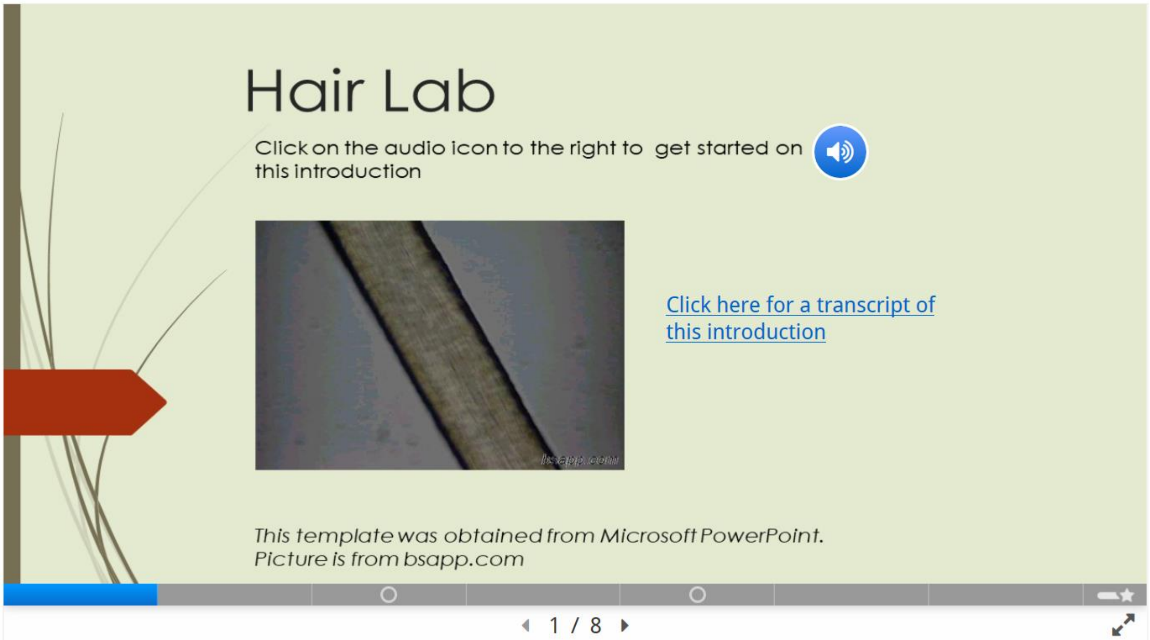
Constructing explanations and designing solutions for this laboratory centered around three areas (Table 4.11). Most students used valid and reliable sources to make explanations (average scores 2.77), scientific reasoning to link evidence to claims (average scores 2.73), and evidence to design a solution to a real-world problem (average score 2.82). One student did not answer the questions in this section, while a second supplied very limited answers. Another did not correct an incorrect hypothesis. Two students did not explain why the hypothesis was correct or incorrect. Finally, two students did not consider the differences between the population being tested and the general population. Having students look up the rates of fingerprint types in the United States could help them better reflect on how their samples could be different from the general population.

Table 4.11 Constructing Explanations and Designing Solutions Scores from the NGSS SEPs Rubric for the Fingerprint Laboratory

Constructing Explanations and Designing Solutions SEPs for the At-Home Fingerprint Laboratory	Average Score (out of 3)
Uses student investigations, models, and theories as appropriate to make explanations	2.77
Correctly uses ideas from theories and laws to make clear explanations	2.77
Correctly and clearly uses scientific reasoning, theory, and/or models as applicable to link evidence to the claims	2.73
Correctly assesses the extent to which the reasoning and data support the explanation or conclusion	2.73
Correctly uses scientific knowledge, student-generated sources of evidence, prioritized criteria and tradeoff considerations to design, evaluate, and/or refine a solution to a complex real-world problem	2.82

At-Home Hair Laboratory NGSS SEP Use

This was the first laboratory where supplies were a considerable issue for intervention students. Therefore, I created an alternative laboratory assignment using picture samples from the Internet. Despite this alternative, the laboratory completion rate was still low (57%). However, the students doing the assignment scored an average of 90%. Adding the alternative assignment to the course could make it more available for students and increase completion rates. Below is a screenshot of the first page of this introduction (Picture 5).



Picture 5. Screenshot from the Hair Lab Introduction

For analyzing and interpreting data (Table 4.12), six students did not complete the table, one student did not finish the laboratory, and one student did not add pictures. This led to these average scores: tables (2.44), technology (2.83), clarity (2.89), and valid and scientific claims (2.89). The main reason for having an incomplete table was not being able to obtain the quality materials needed, such as a microscope, to correctly complete the table. Even though materials were an issue in this laboratory, students were still able to compare the similarities and differences in the samples and earn high scores for making valid and scientific claims.

Table 4.12 Analyzing and Interpreting Data Scores from the NGSS SEPs Rubric for the Hair Laboratory

Analyzing and Interpreting Data SEPs for the At-home Hair Laboratory	Average Score (out of 3)
Includes correctly designed tables	2.44
Data analysis uses technology correctly when asked	2.83
Data display is clear	2.89
Claims are valid and scientific	2.89

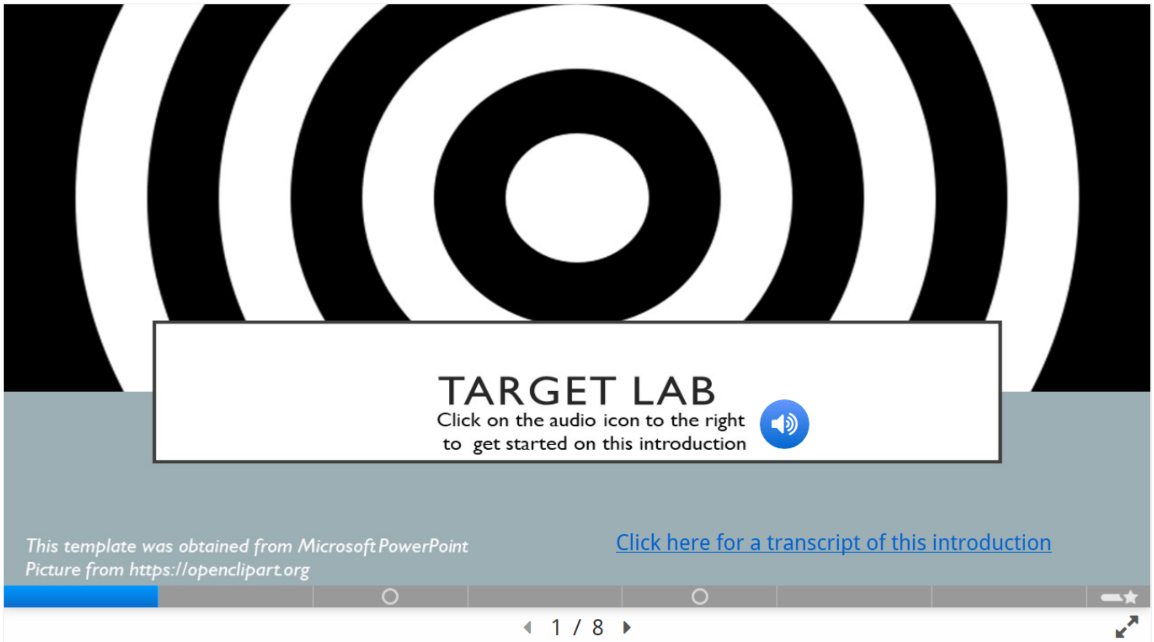
Constructing explanations and designing solutions for the hair laboratory were similar to those in the fingerprint laboratory (Table 4.13). Students earned similar scores for using valid and reliable sources to make explanations (average scores 2.72 and 2.67), scientific reasoning to link evidence to claims (average scores 2.78), and evidence to design a solution to a real-world problem (average score 2.78). Two students did not complete this section. Other reasons for not earning full credit on this section included not analyzing the hypothesis, discussing that DNA was needed for comparisons, and needing to work on differences.

Table 4.13 Constructing Explanations and Designing Solutions Scores from the NGSS SEPs Rubric for the Hair Laboratory

Constructing Explanations and Designing Solutions SEPs for the At-Home Hair Laboratory	Average Score (out of 3)
Uses student investigations, models, and theories as appropriate to make explanations	2.72
Correctly uses ideas from theories and laws to make clear explanations	2.67
Correctly and clearly uses scientific reasoning, theory, and/or models as applicable to link evidence to the claims	2.78
Correctly assesses the extent to which the reasoning and data support the explanation or conclusion	2.78
Correctly uses scientific knowledge, student-generated sources of evidence, prioritized criteria and tradeoff considerations to design, evaluate, and/or refine a solution to a complex real-world problem	2.78

Simulation Target Laboratory NGSS SEP Use

This simulation laboratory requiring intervention students to make a ball hit a target was not completed by as many students as the laboratories in units one and two. Eighty-three percent of students completed the laboratory with an average score of 87%. Perhaps this is because the content was different, or students lacked the time needed to complete this later laboratory. Below is a screenshot of the first page of this introduction (Picture 6).



Picture 6. Screenshot from the Target Lab Introduction

Analyzing and interpreting data results were as follows (Table 4.14). Students were able to use the technology (average score 3) to move the ball towards the target and come up with optimal design solutions (average score 3). However, 16 had trouble with various scientific and valid claims related to horizontal and vertical motion (average score 1.63). This laboratory could benefit from a more thorough introduction to the content or a live tutoring event to discuss its content.

Table 4.14 Analyzing and Interpreting Data Scores from the NGSS SEPs Rubric for the Target Laboratory

Analyzing and Interpreting Data SEPs for the Simulation Target Laboratory	Average Score (out of 3)
Data analysis uses technology correctly when asked	3
Claims are valid and scientific	1.63
Design solutions are optimal	3

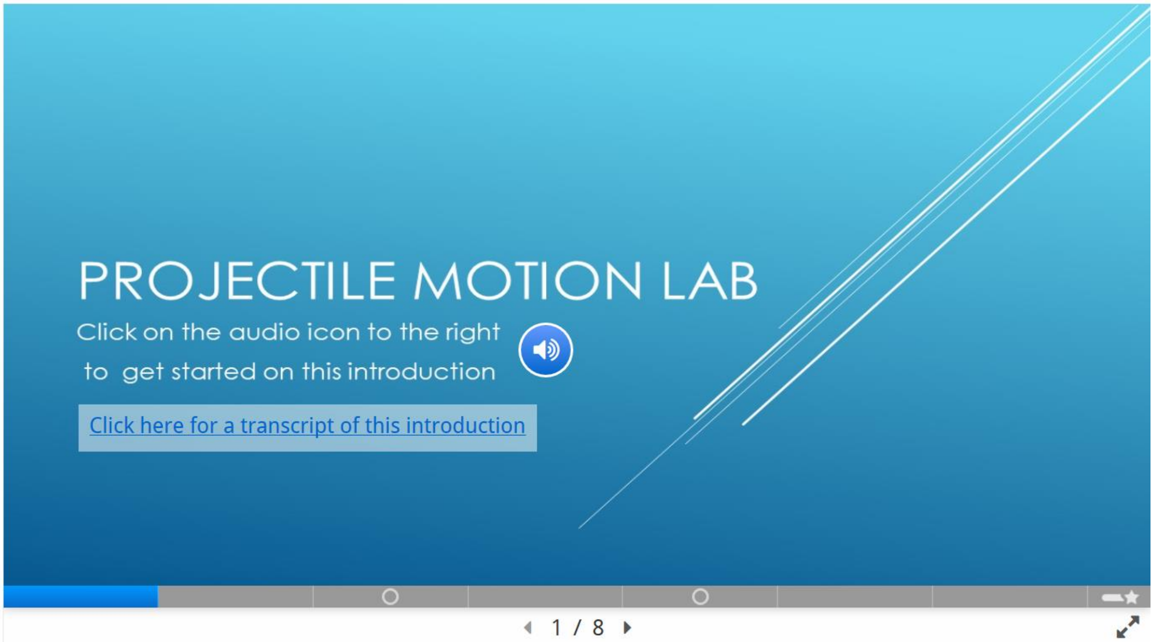
Students were able to share the explanations they constructed despite not entirely understanding the content related to the data analysis (Table 4.15). They were able to give their explanations (both average scores of 2.71) and reasoning and data to support their explanations (both average scores 2.71) about how the object traveled across the path, their hypothesis being true, and the use of ballistics evidence in forensic science.

Table 4.15 Constructing Explanations and Designing Solutions Scores from the NGSS SEPs Rubric for the Target Laboratory

Constructing Explanations and Designing Solutions SEPs for the Simulation Target Laboratory	Average Score (out of 3)
Uses student investigations, models, theories, and simulations as appropriate to make explanations	2.71
Correctly uses ideas from theories and laws to make clear explanations	2.71
Correctly and clearly uses scientific reasoning, theory, and/or models as applicable to link evidence to the claims	2.71
Correctly assesses the extent to which the reasoning and data support the explanation or conclusion	2.71

Simulation Projectile Motion Laboratory NGSS SEP Use

This simulation laboratory consisted of four short laboratories and the opportunity to make a fifth based on student design. The completion rate for this laboratory was 70% with an average score of 93%. The lower completion rate could be because the laboratory had five separate parts and/or was later in the course. Below is a screenshot of the first page of this introduction (Picture 7).



Picture 7. Screenshot from the Projectile Motion Lab Introduction

Intervention students did well analyzing the data for the laboratory (Table 4.16). This laboratory differed from the previous target laboratory in that each factor underwent a separate test. Breaking the content into smaller chunks made making valid and scientific claims easier for students. However, four students did not finish all five laboratories. They completed tables correctly and clearly with average scores of 2.86 for these SEPs. There was one error in setting up the variables for the experiment (average technology score was 2.86) and two errors in describing the content of the laboratory (average for scientific and valid claims was 2.48).

Table 4.16 Analyzing and Interpreting Data Scores from the NGSS SEPs Rubric for the Projectile Motion Laboratory

Analyzing and Interpreting Data SEPs for the Simulation Projectile Motion Laboratory	Average Score (out of 3)
Includes correctly designed tables	2.86
Data analysis uses technology correctly when asked	2.86
Data display is clear	2.86
Claims are valid and scientific	2.48

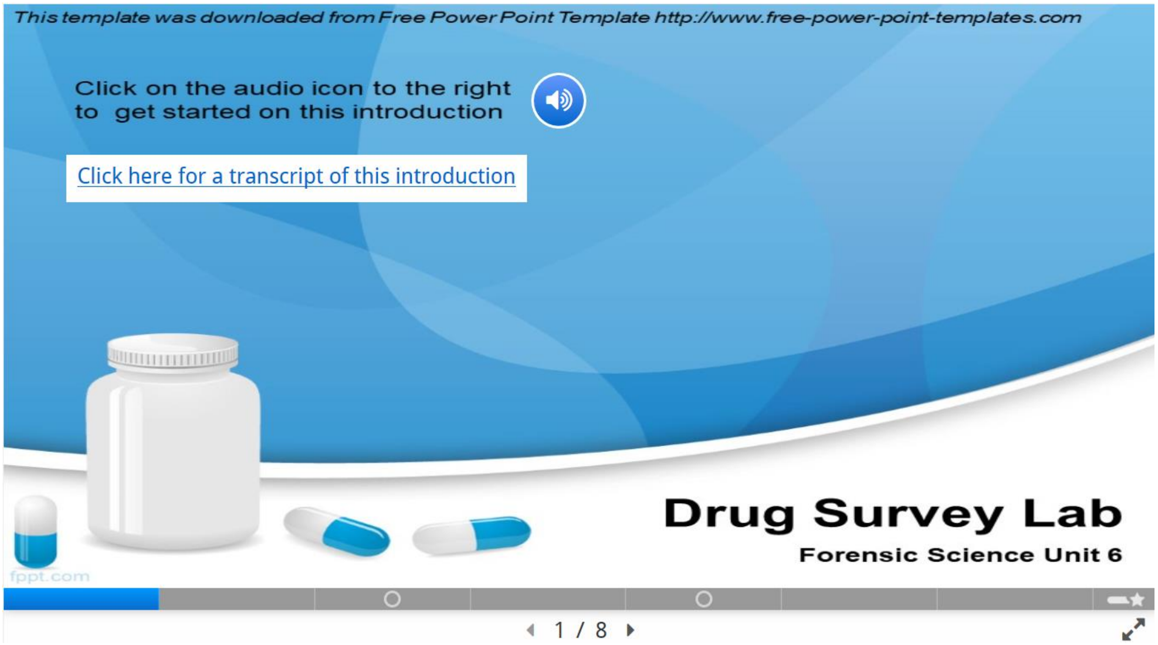
For constructing explanations and designing solutions (Table 4.17), students were able to use valid and reliable sources, including simulations and their investigation, to come up with explanations for the lab (average score 2.48). Students were also able to add ideas from theories and laws when making their explanations (average score 2.33). As mentioned, five students did not complete all the laboratories. Some other errors in this section included describing the content related to the laboratory results, elaborating on what was shown about the hypothesis, describing what needed to be corrected about a hypothesis, and errors in discussing content and concluding results. Students were also able to link reasoning, theory, and data to support conclusions (average scores both 2.43).

Table 4.17 Constructing Explanations and Designing Solutions Scores from the NGSS SEPs Rubric for the Projectile Motion Laboratory

Constructing Explanations and Designing Solutions SEPs for the Simulation Projectile Motion Laboratory	Average Score (out of 3)
Uses student investigations, models, theories, and simulations as appropriate to make explanations	2.48
Correctly uses ideas from theories and laws to make clear explanations	2.33
Correctly and clearly uses scientific reasoning, theory, and/or models as applicable to link evidence to the claims	2.43
Correctly assesses the extent to which the reasoning and data support the explanation or conclusion	2.43

At-Home Drug Survey Lab NGSS SEP Use

Seventy-three percent of intervention students completed the drug survey laboratory earning an average score of 92%. The teacher collected survey results from students about which drugs should be tested for in schools and compiled the data for students to use in this laboratory. There is a discussion board about drug tests in schools. Because this was the second assignment about drug testing in schools and there was a link to student survey data about drug tests, this laboratory was confusing to students and needs additional clarification to help students better understand how to complete it. Another idea is to design the discussion board to introduce or supplement the laboratory. Below is a screenshot of the first page of this introduction (Picture 8).



Picture 8. Screenshot from the Drug Survey Lab Introduction

Students successfully analyzed and interpreted the data (Table 4.18). When making the table, one student did not include all the drugs from the survey. For the graph, one student did not make a graph, and two had trouble labeling. This led to the following scores. Graphing and tables was 2.77, using technology was 2.95, and displaying data clearly was 2.82. Students were able to explain their findings with valid and scientific claims (average score of 3). Students were also able to determine the drugs that were selected the most in the survey (statistics average score of 3) as well as determine how sample selection would impact the results (limitation score of 3).

Table 4.18 Analyzing and Interpreting Data Scores from the NGSS SEPs Rubric for the Drug Survey Laboratory

Analyzing and Interpreting Data SEPs for the At-Home Drug Survey Laboratory	Average Score (out of 3)
Includes correctly designed tables and graphs	2.77
Data analysis uses technology correctly when asked	2.95
Data display is clear	2.82
Claims are valid and scientific	3
Effectively uses statistics and probability to address scientific and engineering questions, using digital tools when feasible	3
Correctly considers sample selections when applicable	3

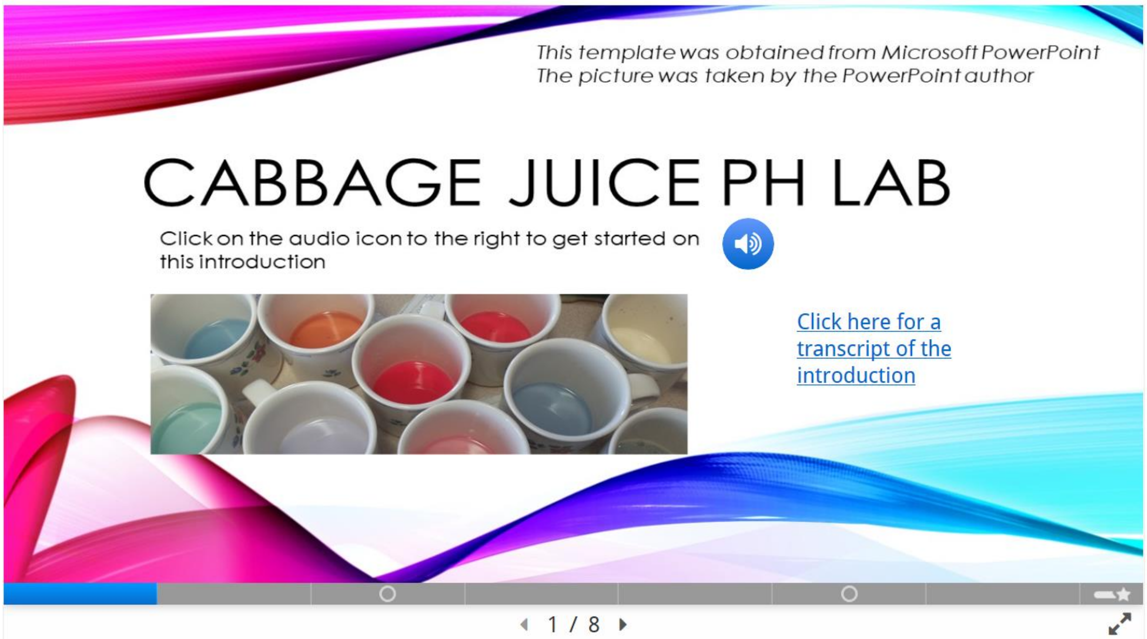
With constructing explanations and designing solutions (Table 4.19), students were able to pick the drugs they thought should be present in drug tests at schools, but nine students did not add enough information about how they came to their conclusions. Also, one student did not answer the questions about the survey question and sample selection. This led to using reasoning, data, and making real-life solutions scores of 2.5.

Table 4.19 Constructing Explanations and Designing Solutions Scores from the NGSS SEPs Rubric for the Drug Survey Laboratory

Constructing Explanations and Designing Solutions SEPs for the At-home Drug Survey Laboratory	Average Score (out of 3)
Correctly and clearly uses scientific reasoning, theory, and/or models as applicable to link evidence to the claims	2.5
Correctly assesses the extent to which the reasoning and data support the explanation or conclusion	2.5
Correctly uses scientific knowledge, student-generated sources of evidence, prioritized criteria and tradeoff considerations to design, evaluate, and/or refine a solution to a complex real-world problem	2.5

<u>At-Home Red Cabbage Laboratory NGSS SEP Use</u>

In this assignment, intervention students boiled red cabbage to use the juice as a pH indicator. The red cabbage laboratory completion rate was 57%. The average score of those completing the laboratory was 93%. The main factors in completing this laboratory were both materials (getting access to the red cabbage) and time. One student asked to reduce the number of samples being tested due to budget. This was the first of two at-home laboratories in the same unit. Below is a screenshot of the first page of this introduction (Picture 9).



Picture 9. Screenshot from the Red Cabbage Lab Introduction

Interpreting and analyzing data scores varied based on the SEP (Table 4.20). Four students did not make a graph. Six students did not change the horizontal axis to cross at 7 (a neutral pH value) to see the acids go down and the bases go up on the graph. One student did not correctly label the graph. The average score for designing tables and graphs was 1.94, for using the technology was 2.13, and for making clear data displays was 2.94. Perhaps highlighting the video about how to change the horizontal axis could improve student understanding of this item. Students were able to explain pH value and identify substances as acids or bases (average score for making valid and scientific claims 3). They were also able to recognize the limits of sample selection (average score 3).

Table 4.20 Analyzing and Interpreting Data Scores from the NGSS SEPs Rubric for the Red Cabbage Laboratory

Analyzing and Interpreting Data SEPs for the At-Home Red Cabbage Laboratory	Average Score (out of 3)
Includes correctly designed tables and graphs	1.94
Data analysis uses technology correctly when asked	2.13
Data display is clear	2.94
Claims are valid and scientific	3
Correctly considers sample selections when applicable	3

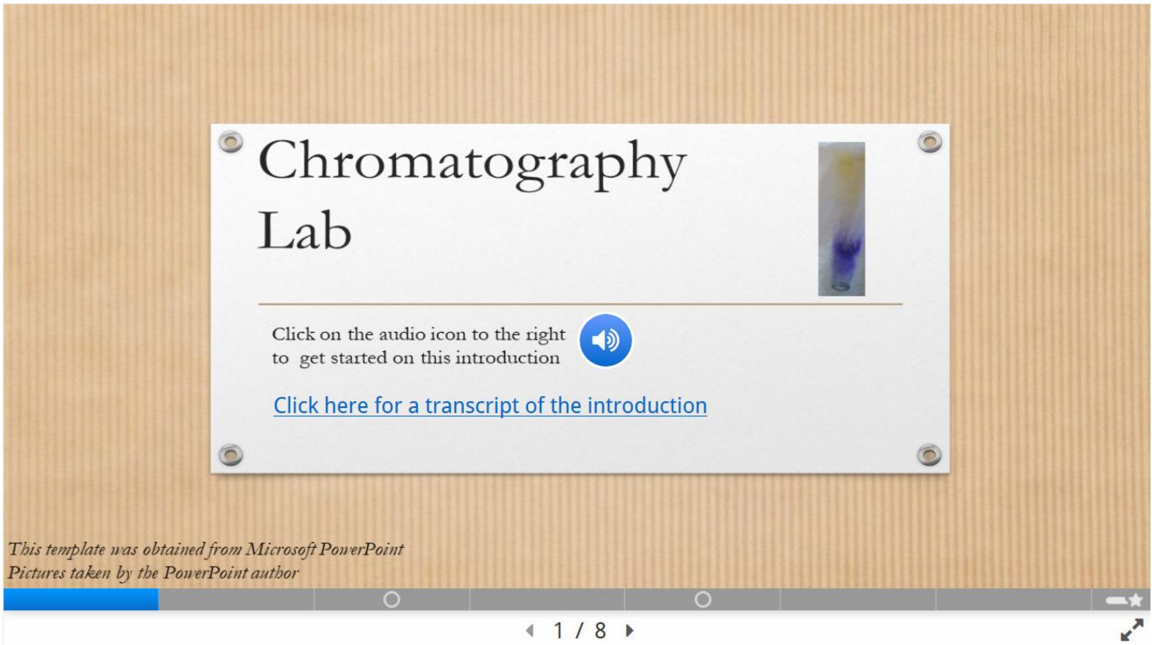
Despite students having difficulties creating the correct graph, they were still able to construct explanations and design solutions (Table 4.21). Students were able to explain the relationship between pH, acids, and bases (average score for using quantitative and qualitative claims and explaining the relationships between variables was 2.88). Two students needed to add more information about claims to their conclusions. Applying findings to patterns in real-life was a struggle for eight students (average score for refining a solution to a real-life problem was 2.24). More information about the uses of acids and bases in the introduction could help improve student understanding of this area.

Table 4.21 Constructing Explanations and Designing Solutions Scores from the NGSS SEPs Rubric for the Red Cabbage Laboratory

Constructing Explanations and Designing Solutions SEPs for the At-Home Red Cabbage Laboratory	Average Score (out of 3)
Correctly and appropriately uses all available quantitative and/or qualitative claims	2.88
Clearly and correctly explains the relationship between independent and dependent variables	2.88
Correctly uses scientific knowledge, student-generated sources of evidence, prioritized criteria and tradeoff considerations to design, evaluate, and/or refine a solution to a complex real-world problem	2.24

At-Home Chromatography Laboratory NGSS SEP Use

Intervention student completion for the chromatography laboratory was similar to the red cabbage laboratory, or 53%, with an average score of 94%. For this second at-home laboratory of the unit, students used chromatography to match the ink of a known pen or marker to an unknown. Students may not have been able to have the materials or time to complete the laboratory. Perhaps, highlighting some alternative materials available to work on the laboratory could help alleviate some supply concerns. Below is a screenshot of the first page of this introduction (Picture 10).



Picture 10. Screenshot from the Chromatography Lab Introduction

For analyzing and interpreting data one student did not complete the table and another did not fill it out correctly leading to reduced scores for tables (average score 2.75), technology (average score 2.88), and clarity (average score 2.81) (Table 4.22).

Table 4.22 Analyzing and Interpreting Data Scores from the NGSS SEPs Rubric for the Chromatography Laboratory

Analyzing and Interpreting Data SEPs for the At-Home Chromatography Laboratory	Average Score (out of 3)
Includes correctly designed tables	2.75
Data analysis uses technology correctly when asked	2.88
Data display is clear	2.81

When constructing explanations and designing solutions, most students were able to correctly identify the unknown pen based on the table they filled in (Table 4.23). However, two students needed to add to their conclusions as the assignment had a sentence requirement. This led to average scores for reasoning and data of 2.81 and an average score for solutions to real-life problems of 2.88.

Table 4.23 Constructing Explanations and Designing Solutions Scores from the NGSS SEPs Rubric for the Chromatography Laboratory

Constructing Explanations and Designing Solutions SEPs for the At-Home Chromatography Laboratory	Average Score (out of 3)
Correctly and clearly uses scientific reasoning, theory, and/or models as applicable to link evidence to the claims	2.81
Correctly assesses the extent to which the reasoning and data support the explanation or conclusion	2.81
Correctly uses scientific knowledge, student-generated sources of evidence, prioritized criteria and tradeoff considerations to design, evaluate, and/or refine a solution to a complex real-world problem	2.88

At-Home Strawberry DNA Extraction Laboratory NGSS SEP Use

For this laboratory, intervention students extracted DNA from a strawberry. Despite being worth only 15 points, 63% of students chose to complete the assignment earning an average score of 93%. Materials were a factor limiting student completion of this laboratory. A virtual demonstration of the laboratory or an alternative materials list could have allowed more students to complete the assignment. Below is a screenshot of the first page of this introduction (Picture 11).

Picture 11. Screenshot from the DNA Extraction Lab Introduction

For analyzing and interpreting data, students did well explaining what the DNA looked like and describing any errors in their work (Table 4.24). This earned students an average of 3 for using technology (adding a picture of the DNA) and clarity (describing the DNA).

Table 4.24 Analyzing and Interpreting Data Scores from the NGSS SEPs Rubric for the DNA Extraction Laboratory

Analyzing and Interpreting Data SEPs for the At-Home DNA Extraction Laboratory	Average Score (out of 3)
Data analysis uses technology correctly when asked	3
Data display is clear	3

The main objective of the laboratory was to see the DNA and then describe the steps of the laboratory for constructing explanations and designing solutions (Table 4.25). Fourteen students had trouble describing the steps of the laboratory, earning an average score of 2.06 for both categories of explanations. The introduction and even previous laboratories can be modified to address the explanation of procedures and help students better articulate why they are completing various laboratory steps.

Table 4.25 Constructing Explanations and Designing Solutions Scores from the NGSS SEPs Rubric for the DNA Extraction Laboratory

Constructing Explanations and Designing Solutions SEPs for the At-Home DNA Extraction Laboratory	Average Score (out of 3)
Uses student investigations, models, theories, and simulations as appropriate to make explanations	2.06
Correctly uses ideas from theories and laws to make clear explanations	2.06

<u>At-Home Blood Splatter Laboratory NGSS SEP Use</u>

The laboratory asked intervention students to create fake blood and then drop it on various surfaces from different heights. It was completed by 50% of the students in the study with an average score of 99%. Below is a screenshot of the first page of this introduction (Picture 12).

Picture 12. Screenshot from the Blood Splatter Lab Introduction

When analyzing and interpreting data (Table 4.26), students successfully completed the table (average score 2.94) and using the technology to add a picture (average score 2.94). One student failed to add the required pictures to supplement descriptions. Despite this, all students were able to give clear (average score 3) and accurate scientific descriptions (average score 3).

Table 4.26 Analyzing and Interpreting Data Scores from the NGSS SEPs Rubric for the Blood Splatter Laboratory

Analyzing and Interpreting Data SEPs for the At-Home Blood Splatter Laboratory	Average Score (out of 3)
Includes correctly designed tables	2.94
Data analysis uses technology correctly when asked	2.94
Data display is clear	3
Claims are valid and scientific	3

These analyzing and interpreting data scores led to students making good explanations (average scores of 2.81) (Table 4.27). The only error in this section was some students did not describe well the impact of height and tended to focus more on the surface. This can be highlighted better in the introduction.

Table 4.27 Constructing Explanations and Designing Solutions Scores from the NGSS SEPs Rubric for the Blood Splatter Laboratory

Constructing Explanations and Designing Solutions SEPs for the At-home Blood Splatter Laboratory	Average Score (out of 3)
Uses student investigations, models, theories, and simulations as appropriate to make explanations	2.81
Correctly uses ideas from theories and laws to make clear explanations	2.81

Key Patterns in Focus NGSS Use Across Laboratories

For intervention students that chose to complete the post-study survey, there was a shift in thoughts about the NGSS SEPs of focus. Participants were better able to articulate these practices, their importance, and how they use them. Study findings also displayed that this translated into effective use of the practices in many aspects of the laboratory activities. However, the findings also reveal areas to target for improvement.

During the laboratories, students had problems making tables and graphs, uploading pictures, and correctly using some aspects of the simulations. A way to shift students to better table and graph creation is by using a unit one tutorial preparing students for this aspect of the laboratory assignments. Such online help can include short lessons on making tables, graphs, uploading pictures, using a simulation laboratory, and contacting technical support. There is already a metric system review in unit one and some pointers on these aspects of laboratories could strengthen student data analysis to provide them with a better understanding of the laboratories. Furthermore, each unit has helpful information about how to upload an entire assignment making that area an easy place to add information on uploading pictures.

Errors in the laboratories for the intervention students also did not seem to diminish over time as they were very dependent on the questions and concepts of the laboratory. For example, student ability to calculate, describe statistics, explain steps, describe the relationship between content and laboratory results, and apply results to real-life varied from assignment to assignment. Therefore, it is important for me and other online science instructors to monitor student understanding of and use of content and SEPs for each laboratory. Then, course instructors can recommend necessary changes to curriculum and other assistance to promote student understanding. For example, based on the results of this study, I can revise the introductions I created to help students successfully complete more aspects of the laboratories. I can also highlight sections of the laboratories in the laboratory introductions, share parts of the introductions when students ask for help by email or virtual tutoring, or explain errors by linking to parts of the introductions when providing feedback.

Chapter Summary

This chapter explained the findings of the study. It explored some background information about the intervention students. Then, the findings were related to the student interactions before the laboratories, laboratory completion, shifts in thoughts about the NGSS focus SEPs, and the use of these SEPs. Such findings helped determine the benefits of the introductions as well as modifications to consider. A discussion of the findings is in the next chapter.

CHAPTER FIVE: DISCUSSION

This chapter discusses the findings of the study and their relationship to academic literature. It first explores some information about the intervention students enrolled in the online course. Then, it examines intervention student-teacher interactions, laboratory completion, shifts in student thoughts about laboratory practices and the focus NGSS SEPs, and the use of the NGSS SEPs in the course laboratories while considering current literature. Finally, I provide implications for future research on how to help online students better interact with their instructors about completing laboratories and thinking about and using NGSS SEPs in their online science courses.

Online Science Students

The data from this study supports the findings of Project Tomorrow (2015) that online courses can be used by administrators to solve problems with scheduling, deliver higher level coursework, and offer classes when instructors are limited. This higher-level science course was chosen by the intervention students because the course was not offered locally to 67%, 13% had scheduling conflicts, and 3% needed the course to fulfill early graduation requirements (Figure 10). Picianno and Seaman (2010) also discuss that high school administrators can use online courses to enhance course offerings, and this can be seen in these demographics.

In addition to making courses available to students, Project Tomorrow (2015) states that some students appreciate online learning because it offers flexibility. In this study, 17% of the students had an online course preference. Initially, students perceived some advantages and disadvantages of taking online science courses. Some advantages they recognized were having the flexibility to complete assignments on their schedule, being provided with a variety of resources to enrich subject matter and learning interesting content with real-life applications. On the other hand, students saw the disadvantages of online courses as limiting teacher interactions, lacking hands-on opportunities, creating problems with obtaining materials, making understanding more difficult, and providing opportunities for procrastination due to flexible scheduling.

Through this study, I, as an online instructor, gained a better understanding of why students enrolled in the intervention forensic science course online as well as the perceived benefits and weaknesses of the online science course format. This information is important in determining what online forensic science students hope to gain by course participation and what is needed to promote course success. With such knowledge, online science instructors can better tailor course design and instruction to promote the highest levels of student achievement. One important aspect of course design is creating opportunities for student-teacher interactions.

Question One: Student-Teacher Interactions

The first question addressed by this study was: Do introductions before online forensic science laboratories focused on key content, procedures, and two NGSS SEPs (analyzing and interpreting data and constructing explanations and designing solutions) promote student interactions with the course instructor by students asking questions before completing the laboratories? Of interest was whether the introductions influenced the frequency of questions students asked regarding procedures, data, or content.

Interactions were a concern to the intervention students. Moore (1991) discusses how differences in geography can lead to transactional distance and the need for teacher dialogue and course design to overcome this barrier to learning. Intervention students may have recognized this transactional distance when participating in the study. One goal of the introductions was to provide a format to explain the laboratories to students and allow them to interact with the content and ask questions of the teacher before completing the laboratories. Before taking the class, 62% of survey respondents agreed or strongly agreed that they would like to study science in an online format. After taking the class, only 41% agreed or strongly agreed that they had liked studying science online. The top reasons students gave for not liking science online was that they missed face-to-face interactions (47%). Therefore, students recognized the lack of face-to-face interactions in online courses as a negative factor. However, introductions to help familiarize students with content, procedures, and two focus NGSS SEPs did not encourage students to interact more with the instructor and did not help fill student needs for student-teacher interactions.

Teacher logs about email/phone communications and survey responses did not show a shift towards elevated levels of student-teacher interactions during this study. At the beginning of the class, most students, or 86%, felt neutral about asking for help from the teacher before a laboratory. By the end of the class, a small majority of students, or 53%, had no questions before the laboratories. Questions were limited and mostly related to procedural aspects such as technology (31%), materials (25%), laboratory steps (19%), and time (16%). A few questions were about data organization (6%) and content (3%). Even though students felt they missed face-to-face interactions with the teacher during the online science class, most did not ask questions before completing the laboratories. The introductions did not lead students towards more interactions with the teacher about the laboratories. The introductions explained the content and directions of the laboratory better. This may have caused a shift towards students asking less questions of the teacher before laboratories. Yet, intervention students expressed missing more face-to-face interactions with their course instructor.

The majority of students, or 70%, agreed or strongly agreed to liking the laboratory introductions. The objectives of the introductions were to add clear expectations (Cohen & Ellis, 2004; DiPietro et al., 2008; iNACOL 2011b; Maryland Online, 2016; Reisetter & Boris, 2009), a focus on key ideas (AAAS, 1990; Bloom et al., 1956; Maryland Online, 2016; Wiggins & McTighe, 2005), activity use (AAAS, 1990; Elbaum, McIntyre, & Smith, 2002; iNACOL, 2011a), and resources (Cys, 1997; DiPietro et al., 2008; iNACOL, 2011a; Jeschofnig & Jeschofnig, 2011; Reisetter & Boris, 2009; Schmidt, 2009; Zhang, 2005;). When creating these resources, I also considered design elements (Cark & Mayer, 2001; Lewis, 2000; Mayer, 2001; Williams, 2004), accessibility (ADA, n.d.; iNACOL, 2011b; McGrath, 2016; U.S. Department of Justice, 2009; W3C, 2018.) and copyright laws (iNACOL, 2011a; Maryland Online, 2016; U.S. Copyright Office, 2016).

The majority of intervention students believed the introductions were helpful when completing the laboratories. Yet, the introductions addressed content, procedures, and focus NGSS SEPs. Student interactions with introductions could not be tracked, and I was unable to determine which aspects of the introductions were most helpful to students. Open-ended intervention student survey responses indicated that students perceived the laboratories were easy to follow and found the videos in the introductions to be helpful. In the future, it is important for me to survey students further about the introductions and track introduction completion and laboratory grades. This information could help me modify the introductions. With such changes the introductions might receive higher approval ratings and become even more helpful to students.

Since courses with teacher interactions are important (iNACOL, 2011a), there can also be other ways to promote interactions before and during laboratories in an online class. Laboratory discussion boards can be a place that students ask questions and discuss laboratories (Jeschofnig & Jeschofnig, 2011). Teachers can respond to student questions, but also allow the opportunity for students to respond to one another. Jeschofnig and Jeschofnig (2011) also discuss the use of video conferencing tools to allow the instructor and students to work through questions together and the use of wikis for students to work on projects with peers. All of these could be active ways to allow students to complete laboratories and collaborate with the teacher and one another.

In addition to providing interactions before or during the laboratories, there is also an opportunity to provide better feedback to students after the laboratory has been submitted (NRC, 2000). While the introductions allowed students to answer basic content and procedural questions, teacher feedback can be more personalized. Feedback as assignments are graded can incorporate components of the introductions and personalize responses to facilitate corrections. Cox-Peterson and Olsen (2012) share how feedback can help students gain a better understanding of concepts. DiPietro et al. (2010) also suggest that it is exemplary online teaching to interact with students and help them improve their understanding.

By understanding student thoughts about laboratory help in this online forensic science class, science instructors can begin to identify the types of student-teacher interactions that are most helpful for online students. Then, these opportunities for high quality interactions can be carefully designed and well-placed in courses. One anticipated outcome of such interactions is increased rates of laboratory completion.

Question Two: Laboratory Completion

The second research question considered during this study was: Do introductions before online forensic science laboratories focused on key content, procedures, and two NGSS SEPs (analyzing and interpreting data and constructing explanations and designing solutions) promote student completion of those laboratories? Of specific attention was whether the introductions influenced intervention student laboratory completion and laboratory scores when compared to the comparison class. Another concern was if there was a difference in completion rates for simulation and at-home laboratories for intervention students.

When the intervention students started the class, 90% expected to complete all the laboratories. However, once actually working through the class their completion was less than expected. For example, only 67% did all four of the simulation laboratories and 44% did all eight of the at-home laboratories (Figures 16 & 19).

Simulation laboratory completion was higher than at-home laboratories. According to Jeschofnig and Jeschofnig (2011), simulation laboratories are interactive and computer-based. Students usually like these activities. Some of their benefits, according to Scalise et al. (2011) are that they help give students access to laboratories at a reduced cost and time commitment. However, the survey results indicated that 80%

expected to like these laboratories, but only 50% actually did (Figure 22). Some weaknesses of these laboratories are that they are passive and don't allow for hands-on science (Jeschofnig & Jeschofnig, 2011). These could be reasons why the laboratories weren't liked by the intervention students as much as expected.

Despite having a lower number of students enjoying simulation laboratories, the scores of the students who completed these laboratories averaged 87% or better for each simulation laboratory (Figure 18). High levels of achievement were also found in previous K-12 studies of simulation laboratory activities (Khlar, Triona, & Williams, 2007; Pyatt & Sims, 2013; Shegog et al., 2012).

Student expectations about at-home laboratories were initially 50% agreeing or strongly agreeing that they would like the at-home laboratories. For those completing the laboratories, the average laboratory score was 86% or higher for all the at-home laboratories (Figure 21). However, only 41% ended up agreeing or strongly agreeing that they actually liked the at-home laboratories (Figure 23). While students expressed missing "hands-on" activities online, they did not embrace the at-home laboratories as great "hands-on" experiences in this online forensic science course.

Reasons why students did not complete laboratory assignments included problems obtaining materials (41%), lack of time (41%), and the level of work involved (12%). Jeschofnig and Jeschofnig (2011) share that these types of laboratories offer hands-on activities, but also highlight that some of the problems with them are that they are simple, add to student costs by requiring materials, and increase the amount of time students spend on classes. The findings of this study support this claim with materials and time being the major obstacles to at-home laboratory completion. Considerations about the constraints of at-home laboratories should occur.

Jeschofnig and Jeschofnig (2011) highlight some ways to make materials available to students by offering teacher created laboratory kits or commercial products. In the online format of the intervention class, materials could be made available for site coordinators to provide to students. Another idea to make students more aware about course laboratory supplies is offering students a materials list at the beginning of the class and a calendar of laboratory due dates. Tutorials can also be crafted to prepare students for laboratories. That way students can be better prepared for laboratories by being given more explicit instructions as recommended by online course design standards (Maryland Online, 2016), iNACOL's (2011b) online teaching standards, and other research (Cohen & Ellis, 2004; Thomson, 2010). Other ideas could be to provide students with more incentive to complete the laboratories by offering students a laboratory grade or creating an adaptive release for unit tests based on laboratory report progress.

Intervention students saw the opportunity to participate in "hands-on" activities during online laboratories as a positive. However, the "hands-on" nature of the at-home laboratories and completing laboratories were both seen as disadvantages to intervention students. Some intervention students expressed an interest in other types of online activities and not laboratories. Additional online course activities could be created with an emphasis on active learning and higher-level thinking (iNACOL, 2011a). Elbaum, McIntyre, and Smith (2002) further suggest that activities be rich and relevant.

Alternative assignments and virtual demonstrations can be a way to strengthen student completion and understanding of the topics for at-home laboratories. Online demonstrations can allow students to engage with laboratories without purchasing materials. Teachers can also create projects that offer students similar learning experiences without the need for materials. For example, some intervention students expressed the use of laboratory practices in non-laboratory activities. When completing the post-survey questions, 12% identified the criminal case assignments for the class as a place they analyzed and interpreted data. This finding suggests the potential of student NGSS SEPs learning through well-designed alternative assignments.

This section shows that online teachers can better design laboratories and course activities in general to move towards higher rates of student completion. With such increased participation in activities, it is possible for students to better reflect on and use the NGSS SEPs in online courses.

Question Three: Shifts in Student Thoughts

The third research question for this study considered: Do introductions before online forensic science laboratories focused on key content, procedures, and two NGSS SEPs (analyzing and interpreting data and constructing explanations and designing solutions) promote student thinking about the NGSS SEPs? Of main concern was what the shifts in thinking were.

Intervention students did not show an increase in interest in any of the focus NGSS SEPs (Table 4.3). Furthermore, these learners expressed that they did not enjoy online laboratories as much as expected. One goal of the NGSS is to promote student entrance into STEM fields (NGSS, 2013e). The NGSS SEPs should also enhance student engagement and produce positive awareness of science (NGSS, 2013e). Therefore, creating meaningful online laboratory experiences that better interest students in the

NGSS SEPs could be beneficial in achieving the goals of the NGSS. Perhaps alleviating material and time constraints could help students gain more enjoyment of the SEPs and online science courses.

Despite the lack of increased enjoyment of the focus SEPs, post-study intervention students were able to define, express the importance of, and their use of each. There was a shift in student responses about interpreting and analyzing data. This SEP was originally understood as a way to present data and responses shifted to this SEP being important in helping individuals apply the knowledge presented in data by the end of the study. Correspondingly, constructing explanations and designing solutions showed a shift in student thoughts from many intervention students not understanding this SEP to students seeing how data can be used to explain ideas and solve problems. Therefore, presenting the students with information about the laboratories and the SEPs during the introductions helped students better engage with and understand the focus SEPs for each laboratory. This engagement can allow students to better understand the SEPs and science knowledge formation (NGSS 2013b).

Helping students better engage with the NGSS SEPs during online laboratories is very important both in meeting science standards and developing student awareness about their science learning. By recognizing the NGSS SEPs in science courses and their importance, students can focus on better using them during laboratories.

Question Four: Use of the NGSS SEPs

The fourth research question was: Do introductions before online forensic science laboratories focused on key content, procedures, and two NGSS SEPs (analyzing and interpreting data and constructing explanations and designing solutions) promote student use of those NGSS SEPs in laboratory responses? A key interest was the quality of student use for each laboratory assignment.

In this study, the focus NGSS SEPs were analyzing and interpreting data and constructing explanations and designing solutions. Analyzing and interpreting data is one's ability to show data patterns, mathematical relationships, limits, etc. (NGSS, 2013b). Constructing explanations and designing solutions is using information to create understanding by establishing the relationships between variables (NGSS, 2013b). NGSS SEP use seemed to vary across both laboratories and practices. Through repeated focus on key concepts and SEPs, intervention students had the opportunity to understand content and science skills in a variety of ways. This is supported by the NRC's (2012) vision of concentrating on student learning and skill development over time and using both knowledge and practices together. As the AAAS (1990) states, students need to use skills such as critical thinking, analysis, communication, and argument construction over time.

Therefore, the format of repeated use of the NGSS during the course could be a good way to move students towards greater conceptual understanding and scientific skill development. DiPietro et al. (2010) shares how effective online instructors monitor student progress and improve student learning. Cohen and Ellis (2004) describe the importance of instructor to student feedback over time. Scalise et al. (2011) supports science classes offering multiple laboratories. In this forensic science course use of the NGSS SEPs depended on the SEP being used and the laboratory being completed. Therefore, while students were able to show proficiency in a variety of SEPs, there are still opportunities to modify the introductions to better address student weaknesses in the use of the SEPs.

There are some ideas to strengthen online student laboratories. These include continuing to focus on inquiry in laboratories (NRC, 2000) and improving simulation laboratory activities by making them more authentic (Scalise et al., 2011). Another way to help improve online laboratories is through support. Scaffolding and teacher support can be very important in helping students to achieve better goals from laboratories (D'Costa & Schuleter, 2013; Scalise et al., 2011). Therefore, laboratories and instructions can continue to be modified with tutorials, highlighting available student help, and providing feedback to increase their effectiveness and meet the needs of all learners as they try to master the NGSS SEPs in online science classes.

Synthesis

The results of this study can be linked across the research questions. This study explored the relationships between student interactions, laboratory completion, and thoughts about and use of NGSS SEPs after adding laboratory introductions to an online forensics course. There was a shift towards less student-teacher interactions before laboratories, greater laboratory completion, better understanding of NGSS SEPs, and good use of the SEPs throughout the laboratories with some areas of weaknesses.

The study showed that the introductions to content, procedures, and two focus NGSS SEPs before laboratories did not increase student interactions with the instructor. However, this lack of student-teacher interaction did not lead to decreased laboratory completion. In fact, students were more likely to complete laboratories after the addition of the introductions to the course. Yet, the increase in laboratory completion was limited by lack of materials, time, and willingness to exert mental effort. This was especially seen in the completion rates of the at-home laboratories. Considering and implementing other interventions could better increase both student-teacher interactions and laboratory completion.

Additionally, by providing information about the two focus NGSS SEPs (analyzing and interpreting data and constructing explanations and designing solutions), students were better able to describe these SEPs, their importance, and their use. This did not lead to an increased student interest in the SEPs, but students were able to use the SEPs in a variety of laboratory activities. There was not an improvement in SEP use over time. Instead, SEP use varied depending on the laboratory assignment. Therefore, the study revealed areas where student use of SEPs could be strengthened by further interventions.

Future Study Recommendations

This study explored how online simulation and at-home laboratories received enhancements through introductions. However, there is much more to learn about student utilization of the NGSS SEPs in online science courses. Some ideas for future studies related to high school science online include a deeper exploration of:

- why students take online science classes and what courses should contain to meet their learning needs.
- how important laboratory interactions are to online high school science students and what kinds of interactions (tutorials, discussion boards, videoconferencing, student work sites, feedback, etc.) they most want.

- what are the biggest obstacles to completing online laboratories (time, materials, or something else) and what are the best ways to reduce these barriers (making materials available, online laboratory demonstrations, or alternative projects).
- what are some ways that online science courses can increase student interest in engaging with the NGSS SEPs.
- what course supports (scaffolding, teacher guidance, laboratory activity revisions) are most wanted and/or needed by students.

Conclusions

This chapter related the findings of the study to literature in the field. It considered the reason intervention students enrolled in the online forensic science class, student-teacher interactions surrounding the laboratory introductions, laboratory completion, shifting thoughts about the focus NGSS SEPs, and student use of the NGSS SEPs in the study laboratories. Through the study, I shared introductions as one possible way to help students better engage with science content and NGSS SEPs in a high school online science course as well as provided some possible ideas for future exploration.

The study provided information related to the online science students, the types of interactions that are most helpful to them, the barriers that keep them from completing certain online laboratories, and their thoughts about and use of the focus NGSS SEPs throughout the study course. It offered a possible intervention, introductions before laboratories, as a way to help online students master content and NGSS SEPs. This intervention showed some improvements to online laboratory completion and thoughts about and use of NGSS SEPs, but also laid a foundation for future research to build upon when exploring online science laboratories.

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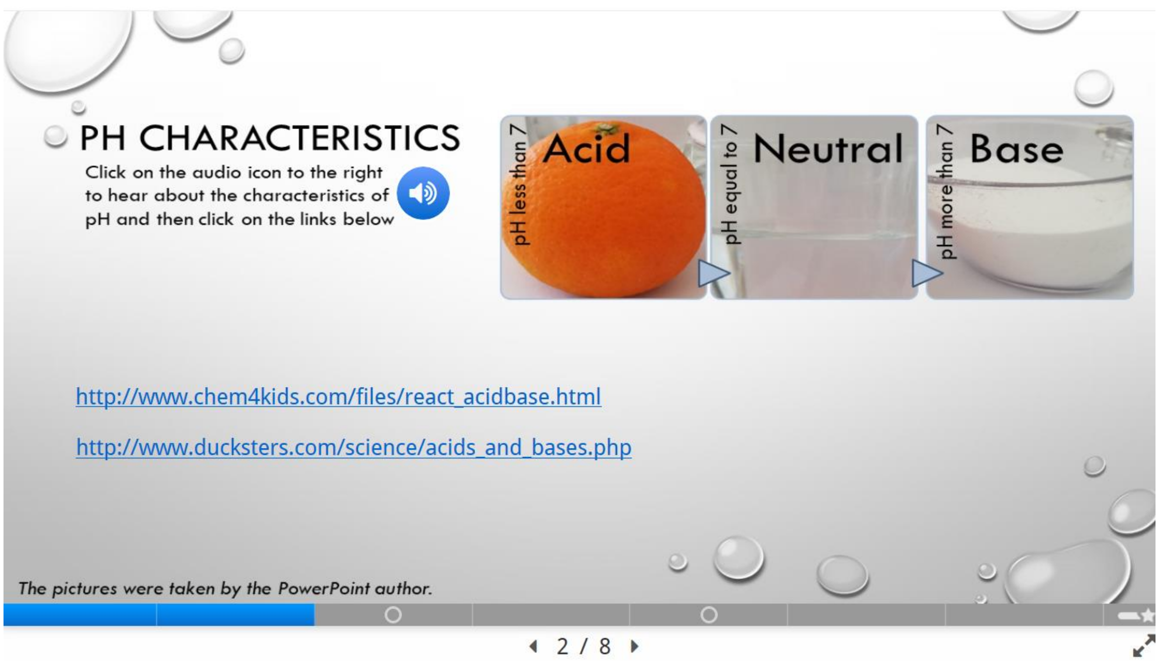
APPENDIX A

Screenshots of the pH Introduction

The introduction for these pH Laboratory screenshots (Pages 1-7) is found at https://h5p.org/node/89070.



CONTENT QUESTIONS

Click on the audio icon to the right to hear the questions and answers

Fill in the missing words

_______ is a measure of the hydrogen ions in a solution.

Substances with a pH of 7 are _______.

Substances with a pH greater than 7 are _______.

Substances with a pH less than 7 are _______.

Water can make acids and bases _______.

Check

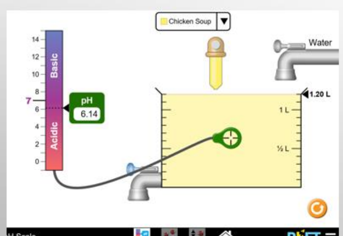
3 / 8

PROCEDURES

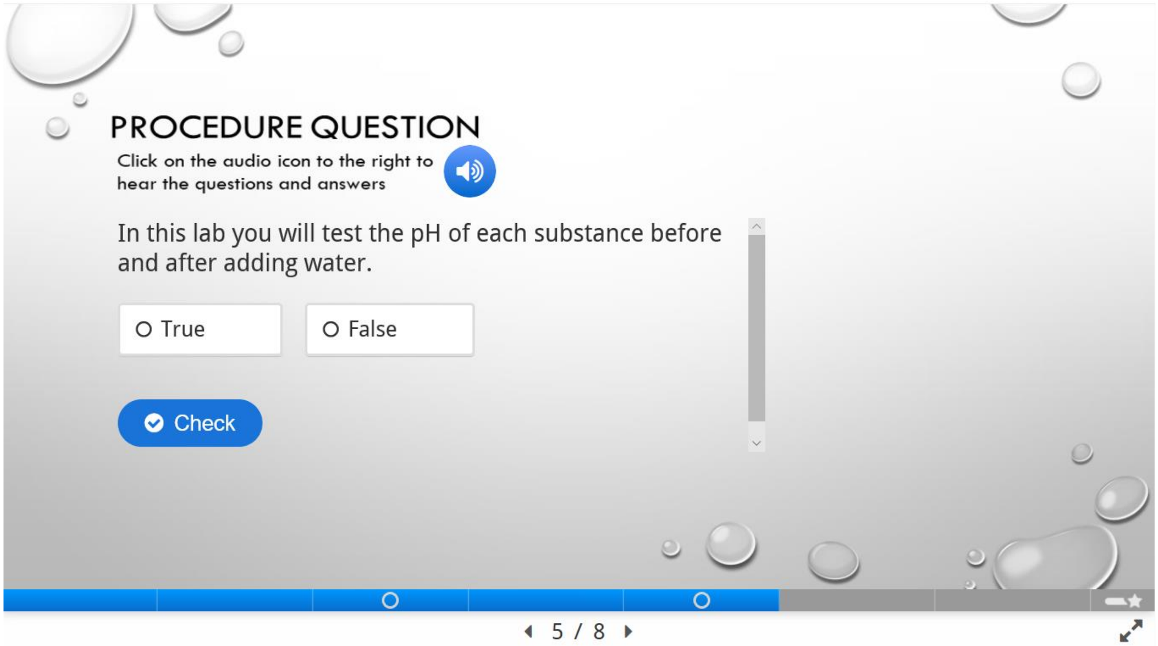
Go to https://phet.colorado.edu/sims/html/ph-scale/latest/ph-scale_en.html

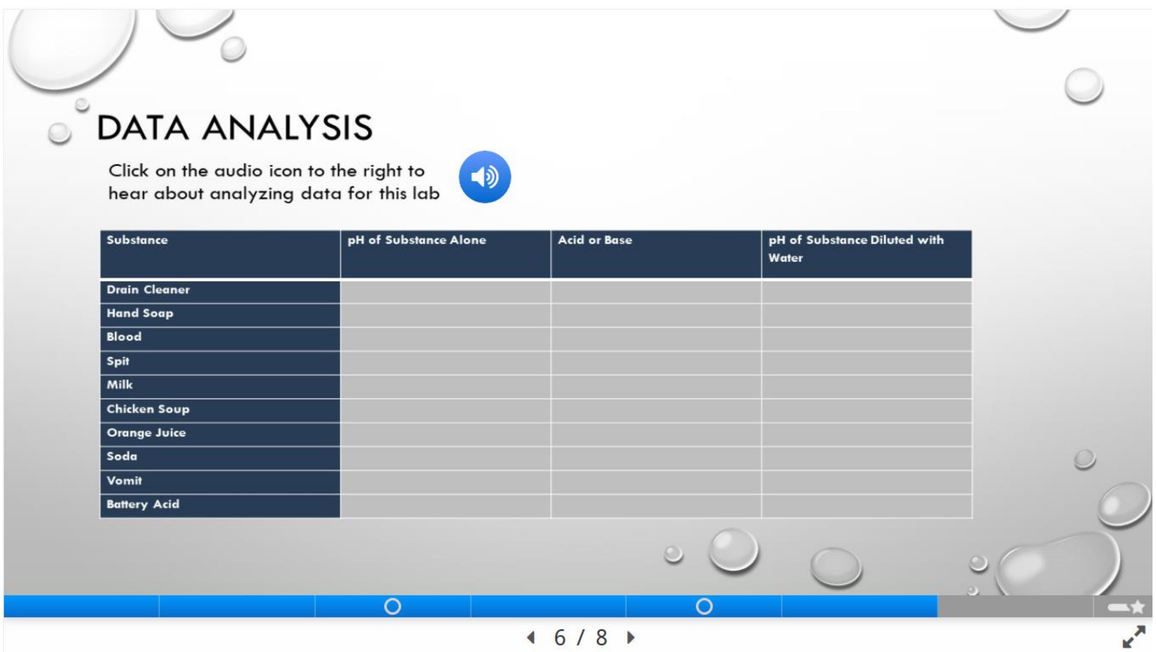
Follow the lab instructions

[Click here to watch a video to help you get started on the lab]()

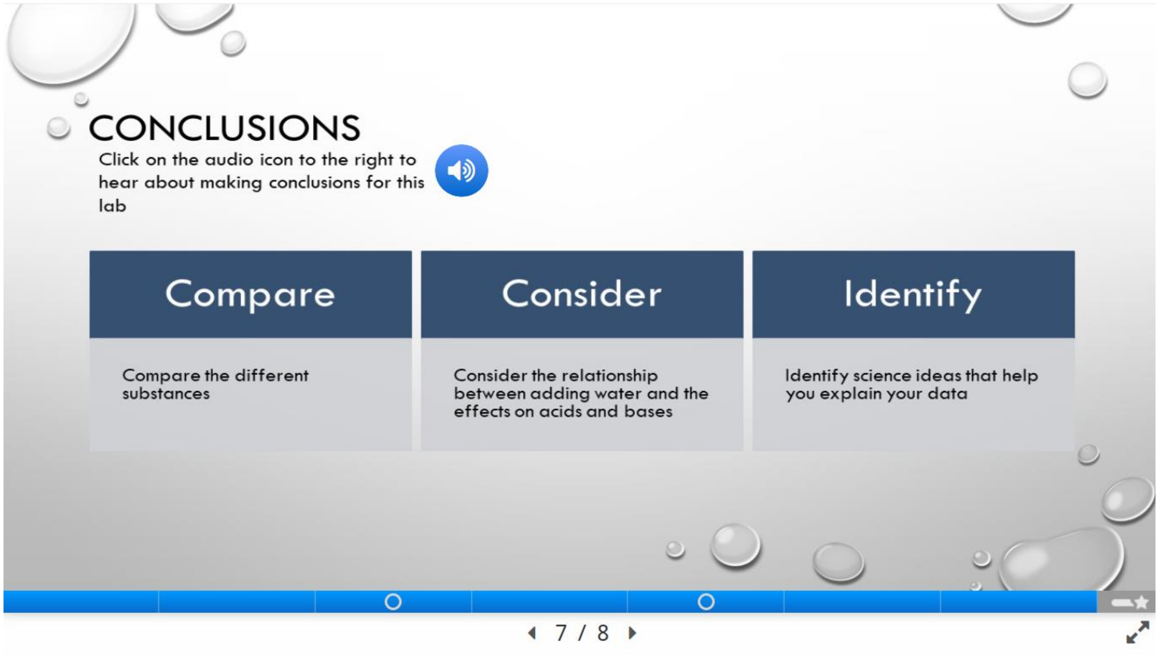


4 / 8





Substance	pH of Substance Alone	Acid or Base	pH of Substance Diluted with Water
Drain Cleaner			
Hand Soap			
Blood			
Spit			
Milk			
Chicken Soup			
Orange Juice			
Soda			
Vomit			
Battery Acid			


CONCLUSIONS
Click on the audio icon to the right to hear about making conclusions for this lab
Compare
Compare the different substances
Consider
Consider the relationship between adding water and the effects on acids and bases
Identify
Identify science ideas that help you explain your data
7 / 8

APPENDIX B

Pre-Study Survey Questions

	Survey Question	Likert or Open
Introduction Questions	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I think introductions explaining laboratories will be helpful.	Likert
Introduction Questions	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I like to get teacher help before starting a laboratory.	Likert
Introduction Questions	What kind of questions do you usually have about laboratories?	Open
Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I like studying science.	Likert

Interest	What do you like and dislike about studying science?	Open
Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I think I will enjoy studying science online.	Likert
Interest	What do you think are some advantages and disadvantages of online classes?	Open
Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree This class has simulation laboratories. Simulation laboratories are laboratories that are done using the Internet. I think I will like the online simulation laboratories for this class	Likert
Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree This class has laboratories to complete at home. I think I will like the at-home laboratories for this class.	Likert

Interest	What do you like best about completing laboratories?	Open
Completion	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I tend to skip assignments in science that are hard.	Likert
Completion	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I am planning to complete all the laboratories for this class.	Likert
Completion	What are some reasons why you might skip a laboratory assignment?	Open
Completion	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I keep working on my science studies until I understand the concepts being discussed.	Likert

Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I like to use tables to make scientific claims or figure out best design solutions.	Likert
Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I like to use graphs to make scientific claims or figure out best design solutions.	Likert
Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I like to use models to make scientific claims or figure out best design solutions.	Likert

Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I like to use technology to make scientific claims or figure out best design solutions.	Likert
Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I like to use statistics and probability with digital tools to answer science and engineering questions.	Likert
Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I like to think about the limits of my data, such as error and sample size, and how to improve studies in the future.	Likert

Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I like to look for what is the same and what is different about my findings and other data.	Likert
Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I like to consider how new data will impact my explanations.	Likert
Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I like to use data to optimize design features or characteristics for success.	Likert

Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I like to use data to determine the relationship between variables in an experiment.	Likert
Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I like to make explanations considering data, models, theories, simulations, and help from peers.	Likert
Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I like using laboratory data, scientific ideas, principles, and evidence to explain laboratory findings, thinking about unanticipated effects.	Likert

Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I like to use reasoning, theories, and models to match evidence with claims to determine if an explanation has support.	Likert
Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I like developing realistic solutions to problems based on science ideas and evidence after considering the importance of various criteria and making tradeoffs.	Likert
Use	What do you think are some important practices to use when completing science laboratories?	Open
Use	What is analyzing and interpreting data?	Open
Use	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree	Likert

	I am good at analyzing and interpreting data.	
Interest	Why is analyzing and interpreting data important?	Open
Use	Share an example of how you have analyzed and interpreted data in the past.	Open
Use	What is constructing explanations and designing solutions?	Open
Use	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I am good at constructing explanations and designing solutions.	Likert
Interest	Why is constructing explanations and designing solutions important?	Open
Use	Share an example of how you have constructed explanations and designed solutions in the past.	Open

APPENDIX C

Post-Study Survey Questions

Post-Study Survey Questions

	Survey Question	Likert or Open
Introduction Questions	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I think introductions explaining laboratories were helpful.	Likert
Introduction Questions	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I liked getting teacher help before starting a laboratory.	Likert
Introduction Questions	What kind of questions did you ask about the laboratories for this class?	Open
Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree	Likert

	I liked studying science in this class.	
Interest	What did you like and dislike about studying science in this class?	Open
Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I enjoyed studying science online.	Likert
Interest	What do you think were some advantages and disadvantages of this online class?	Open
Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree This class has simulation laboratories. Simulation laboratories are laboratories that are done using the Internet. I liked the online simulation laboratories for this class	Likert
Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree	Likert

	This class has laboratories to complete at home. I liked the at-home laboratories for this class.	
Interest	What did you like best about completing laboratories?	Open
Completion	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I tended to skip assignments that were hard in this science class.	Likert
Completion	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I completed all the laboratories for this class.	Likert
Completion	What are some reasons why you skipped a laboratory assignment?	Open
Completion	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree	Likert

	1 Strongly disagree I kept working on my science studies until I understood the concepts being discussed in this class.	
Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I like to use tables to make scientific claims or figure out best design solutions.	Likert
Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I like to use graphs to make scientific claims or figure out best design solutions.	Likert
Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree	Likert

	I like to use models to make scientific claims or figure out best design solutions.	
Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I like to use technology to make scientific claims or figure out best design solutions.	Likert
Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I like to use statistics and probability with digital tools to answer science and engineering questions.	Likert
Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I like to think about the limits of my data, such as error and sample size, and how to improve studies in the future.	Likert

Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I like to look for what is the same and what is different about my findings and other data.	Likert
Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I like to consider how new data will impact my explanations.	Likert
Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I like to use data to optimize design features or characteristics for success.	Likert

Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I like to use data to determine the relationship between variables in an experiment.	Likert
Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I like to make explanations considering data, models, theories, simulations, and help from peers.	Likert
Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I like using laboratory data, scientific ideas, principles, and evidence to explain laboratory findings, thinking about unanticipated effects.	Likert

Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I like to use reasoning, theories, and models to match evidence with claims to determine if an explanation has support.	Likert
Interest	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I like developing realistic solutions to problems based on science ideas and evidence after considering the importance of various criteria and making tradeoffs.	Likert
Use	What do you think are some important practices to use when completing science laboratories?	Open
Use	What is analyzing and interpreting data?	Open
Use	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree	Likert

	I am good at analyzing and interpreting data.	
Interest	Why is analyzing and interpreting data important?	Open
Use	Share an example of how you have analyzed and interpreted data in the past.	Open
Use	What is constructing explanations and designing solutions?	Open
Use	Rate this statement on a scale from 1-5 5 Strongly agree 4 Agree 3 Neutral 2 Disagree 1 Strongly disagree I am good at constructing explanations and designing solutions.	Likert
Interest	Why is constructing explanations and designing solutions important?	Open
Use	Share an example of how you have constructed explanations and designed solutions in the past.	Open

APPENDIX D

Next Generation Science Standards Focus Science and Engineering Practices

Rubric

Analyzing and Interpreting Data

Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.

3	2	1	0	No Opportunity to Use
Effectively uses tools, technology, and/or models to make valid and reliable scientific claims or determine optimal design solutions	Uses tools, technology, and/or models to make valid and reliable scientific claims with minimal errors	Uses tools, technology, and/or models to make valid and reliable scientific claims with many errors	Does not use tools, technology, and/or models to make valid and reliable scientific claims	N/A
Includes correctly designed tables, graphs, and/or a model	Has 1-2 errors in tables, graphs, or a model	Has more than 2 errors in tables, graphs, or a model		
Data analysis correctly uses technology when asked	Data analysis uses technology when asked with 1-2 errors	Data analysis does not use technology when asked or uses technology with more than 2 errors		
Data display is clear	Data display is mostly clear with 1-2 errors	Data display is unclear with more than 2 errors		
Claims are valid and scientific	Claims are mostly valid and scientific with 1-2 errors	Claims are not valid and scientific with more than 2 errors		

Design solutions are optimal	Design solutions are close to optimal with 1-2 errors	Design solutions are not optimal with more than 2 errors		
Concepts used:				

Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.

Effectively uses statistics and probability to address scientific and engineering questions, using digital tools when feasible	Uses statistics and probability to address scientific and engineering questions, using digital tools when feasible with minimal errors	Uses statistics and probability to address scientific and engineering questions, using digital tools when feasible with many errors	Does not use statistics and probability to address scientific and engineering questions, using digital tools when feasible	N/A
Correctly uses function fits, slope, intercept, and/or correlation coefficient as applicable	Uses function fits to data, slope, intercept, and/or correlation coefficients as applicable with 1-2 errors	Uses function fits to data, slope, intercept, and/or correlation coefficients as applicable with more than 2 errors		
Correctly uses digital tools for statistics and probability when asked	Uses digital tools for statistics and probability when asked with 1-2 errors	Does not use digital tools for statistics and probability when asked or uses digital tools when asked with more than 2 errors		
Concepts used:				

Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data.

Effectively uses limitations of data analysis when analyzing and interpreting data	Uses limitations of data analysis when analyzing and interpreting data with minimal errors	Uses limitations of data analysis when analyzing and interpreting data with many errors	Does not use limitations of data analysis when analyzing and interpreting data	N/A
Correctly considers measurement error, sample selections, and other error when applicable	Considers measurement error, sample selections, and other error when applicable with 1-2 errors	Considers measurement error, sample selections, and other error when applicable with more than 2 errors		
Concepts used:				

Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations.

Effectively uses comparisons and contrasts of data to examine consistency of measurements and observations in data	Uses comparisons and contrasts of data to examine consistency of measurements and observations with minimal errors	Uses comparisons and contrasts of data to examine consistency of measurements and observations with many errors	Does not use comparisons and contrasts of measurements and observations	N/A
Correctly compares and contrasts self-generated, archived, and other data when available	Compares and contrasts self-generated, archived, and other data when available with 1-2 errors	Compares and contrasts self-generated, archived, and other data when available with more than 2 errors		

Correctly determines the consistency of measurements and observations	Determines the consistency of measurements and observations with 1-2 errors	Determines the consistency of measurements and observations with more than 2 errors		
Concepts used:				

Evaluate the impact of new data on a working explanation and/or model of a proposed process or system.

Effectively uses evaluation to determine the impact of new data on a working explanation and/or model of a proposed process or system	Uses evaluation to determine the impact of new data on a working explanation and/or model of a proposed process or system with minimal errors	Uses evaluation to determine the impact of new data on a working explanation and/or model of a proposed process or system with many errors	Does not use evaluation to determine the impact of new data on a working explanation and/or model of a proposed process or system	N/A
Correctly explains how new data will impact an explanation and/or model of a proposed process or system	Explains how new data will impact an explanation and/or model of a proposed process or system with 1-2 errors	Explains how new data will impact an explanation and/or model of a proposed process or system with more than 2 errors		
Explanation is clear	Explanation is mostly clear	Explanation is unclear		

Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success.

Effectively uses data analysis to determine design features or characteristics of a process or system to optimize it based on success criteria	Uses data analysis to determine design features or characteristics of a process or system to optimize it based on success criteria with minimal errors	Uses data analysis to determine design features or characteristics of a process or system to optimize it based on success criteria with many errors	Does not use data analysis to determine design features or characteristics of a process or system to optimize it based on success criteria	N/A
Correctly and clearly analyzes design features or characteristics of a process or system	Analyzes design features or characteristics of a process or system with 1-2 errors	Analyzes design features or characteristics of a process or system with more than 2 errors		
Optimizes it based on all success criteria	Comes close to optimizing it based on some success criteria	Does not optimize it based on success criteria		

Constructing explanations and designing conclusions

Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.

Effectively uses quantitative and/or qualitative claims to explain the relationship between independent and dependent variables	Uses quantitative and/or qualitative claims to explain the relationship between independent and dependent variables with minimal errors	Uses quantitative and/or qualitative claims to explain the relationship between independent and dependent variables with many errors	Does not use quantitative and/or qualitative claims to explain the relationship between independent and dependent variables	N/A
Correctly and appropriately uses all available quantitative and/or qualitative claims	Uses most available quantitative and/or qualitative claims	Uses some available quantitative and/or qualitative claims		
Clearly and correctly explains the relationship between independent and dependent variables	Clearly explains the relationship between independent and dependent variables with 1-2 errors	Explanation of the relationship between independent and dependent variables is unclear or contains more than 2 errors		

Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

<table>
<tr><td>Effectively uses a variety of valid and reliable sources to make explanations</td><td>Uses a variety of valid and reliable evidence from a variety of sources to make explanations with minimal errors</td><td>Uses a variety of valid and reliable evidence from a variety of sources to make explanations with many errors</td><td rowspan="3">Does not use valid and reliable evidence from a variety of sources to make explanations</td><td rowspan="3">N/A</td></tr>
<tr><td>Uses student investigations, models, theories, simulations, and peer review as appropriate to make explanations</td><td>Mostly uses student investigations, models, theories, simulations, and peer review as appropriate to make explanations</td><td>Does not appropriately use student investigations, models, theories, simulations, and peer review to make explanations</td></tr>
<tr><td>Correctly uses ideas from theories and laws to make clear explanations</td><td>Uses ideas from theories and laws to make clear explanations with 1-2 errors</td><td>Uses ideas from theories and laws to make clear/unclear explanations with more than 2 errors</td></tr>
<tr><td colspan="5">Sources used:</td></tr>
</table>

Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects

Effectively uses scientific ideas, principles, and/or evidence to construct an explanation of phenomena and solve design problems, considering unanticipated effects	Uses scientific ideas, principles, and/or evidence to construct an explanation of phenomena and solve design problems, considering unanticipated effects with minimal errors	Uses scientific ideas, principles, and/or evidence to construct an explanation of phenomena and solve design problems, considering unanticipated effects with many errors	Does not use scientific ideas, principles, and/or evidence to construct an explanation of phenomena and solve design problems, considering unanticipated effects	N/A
Uses relevant scientific principles, and/or evidence to construct an explanation of phenomena and solve design problems	Uses most relevant scientific principles, and/or evidence to construct an explanation of phenomena and solve design problems with 1-2 errors	Uses some relevant scientific principles, and/or evidence to construct an explanation of phenomena and solve design problems with more than 2 errors		
Correctly considers unanticipated effects	Considers unanticipated effects with 1-2 errors	Considers unanticipated effects with more than 2 errors		

Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.

Effectively uses scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion	Uses scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion with minimal errors	Uses scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion with many errors	Does not use scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation	N/A
Correctly and clearly uses scientific reasoning, theory, and/or models as applicable to link evidence to the claims	Clearly uses scientific reasoning, theory, and/or models as applicable to link evidence to the claims with 1-2 errors	Uses scientific reasoning, theory, and/or models to unclearly or incompletely link evidence to the claims with more than 2 errors		
Correctly assesses the extent to which the reasoning and data support the explanation or conclusion	Assesses the extent to which the reasoning and data support the explanation or conclusion with 1-2 errors	Assesses the extent to which the reasoning and data support the explanation or conclusion with more than 2 errors		

Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

<table>
<tr>
<td>Effectively uses scientific knowledge, student-generated sources of evidence, prioritized criteria and tradeoff considerations to design, evaluate, and/or refine a solution to a complex real-world problem</td>
<td>Uses scientific knowledge, student-generated sources of evidence, prioritized criteria and tradeoff considerations to design, evaluate, and/or refine a solution to a complex real-world problem with minimal errors</td>
<td>Uses scientific knowledge, student-generated sources of evidence, prioritized criteria and tradeoff considerations to design, evaluate, and/or refine a solution to a complex real-world problem with many errors</td>
<td rowspan="2">Does not use scientific knowledge, student-generated sources of evidence, prioritized criteria and tradeoff considerations to design, evaluate, and/or refine a solution to a complex real-world problem</td>
<td rowspan="2">N/A</td>
</tr>
<tr>
<td>Correctly uses scientific knowledge, student-generated sources of evidence, prioritized criteria and tradeoff considerations to design, evaluate, and/or refine a solution to a complex real-world problem</td>
<td>Uses scientific knowledge, student-generated sources of evidence, prioritized criteria and tradeoff considerations to design, evaluate, and/or refine a solution to a complex real-world problem with 1 – 2 errors</td>
<td>Uses scientific knowledge, student-generated sources of evidence, prioritized criteria and tradeoff considerations to design, evaluate, and/or refine a solution to a complex real-world problem with more than 2 errors</td>
</tr>
</table>