ABSTRACT

CHILDERS, GINA MARLENE. Ownership of Data: Students' Investigations with Remote Electron Microscopy. (Under the direction of Dr. M. Gail Jones).

Remote access technologies enable students to investigate science by utilizing scientific tools and communicating in real-time with scientists and researchers with only a computer and an Internet connection. Because remote access technologies offer students unique learning experiences, for the first time in history students can become virtual researchers and collect and share scientific data. The purpose of this study was to identify factors that contribute to successful remote learning investigations, document students' perceptions of ownership of data, science motivation, science identity, learning outcomes in conjunction with a remote investigation, and to document students' perceptions of virtual presence during a remote investigation.

This study, conducted with high school students (n = 72), explored the impact of students' perception of *ownership* of data during a remote investigation. A pretest-posttest control group design was used and students were randomly assigned to one of two treatment groups: students able to collect their own insect to use during the remote investigation (n = 36) and students that did not collect their own insects to view during the remote investigation (n = 36).

The results of this study showed that students' perception of *ownership of data* does not significantly change their perceptions of motivation to do science, science identity, and learning outcomes during a remote investigation. Students' in the experimental group reported being less distracted during the remote investigation than students in the control group, whereas students in the control group reported controlling the technology was easier

than the experimental group. The remote investigation positively influenced students' learning outcomes and students' perception of science identity. Exploratory factor analysis of all identified constructs in the remote investigation indicated that *Science Learning Drive* (students' perception of their competence and performance in science and intrinsic motivation to do science), *Environmental Presence* (students' perception of control of the remote technology, sensory and distraction factors in the learning environment, and relatedness to scientists), and *Inner Realism Presence* (students' perceptions of how real is the remote program and being recognized as a science-oriented individual) are factors that contribute to a successful remote investigation. This study provided valuable information of students' perceptions of motivation, science identity, and virtual presence during a remote investigation that can provide insight into remote learning environments.

Ownership of Data: Students' Investigations with Remote Electron Microscopy

by
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DEDICATION

To my parents, Mike and Lori, and my maternal grandparents, Eugene and Marlene, for teaching me to persevere through all of life's obstacles.

"*The road goes ever on and on*" – J.R.R Tolkien, *The Hobbit*

BIOGRAPHY

Gina Marlene Childers attended North Carolina State University from August 2011 to May 2014.

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"*I am looking for someone to share in an adventure that I am arranging…*" –J.R.R Tolkien, *The Hobbit*.

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CHAPTER ONE

Introduction

Purpose and Significance of the Study

The advent of computer technologies have allowed students to investigate science in novel ways such as remotely accessing telescopes to explore astronomical and scale concepts or accessing scanning electron microscopes to learn about microscopy (Jones, Andre, Superfine, & Taylor, 2003; Jones, Andre, Kubasko, Bokinsky, Tretter, Negishi, Taylor, Superfine, 2003; Lubin & van der Veen, 1992). Remote access technology enables students to use scientific tools and communicate in real-time with scientists anywhere in the world. The use of this new technology in the classroom may have significant implications for student achievement, motivation to do science, perceptions of science identity, and perceptions of ownership of data in a scientific setting.

Because of the rapid technological advancements made during the 21st century, preparing individuals for a technological-based workforce is a necessity (Bybee & Fuchs, 2006). In addition, there is a need for individuals to be scientifically literate in order to effectively question and make decisions based on evidence (Glynn, Brickman, Armstrong, & Taasoobshirazi, 2011). Often, students consider science to be irrelevant, and a lack of student interest in science has some concerned that the United States may have difficulty being a global competitor in the future (Aschbacher, Li, & Roth, 2010). Technology applications are being promoted as one way teachers can promote student learning, motivation, and preparedness for the future (Argyriou, Sevaslidou, & Safeirious, 2010). Lowe, Newcombe, &

Stumpers (2012) suggested that the engagement of students in science classroom laboratories is essential “to [address] a shortfall of students entering science-based professions” (p. 1198). For potential employers, technology skills, which can be developed through the use of remote access technology, are important for employees to master in industry (Maj & Veal, 2011).

The effectiveness of remote access laboratories for student learning and promotion of science concepts with middle school students has rarely been investigated (Ma & Nickerson, 2006; Lowe, Newcombe, & Stumpers, 2012). Although research regarding remote access laboratories exists, many of the articles discuss the development and implementation of remote laboratories in the field of engineering rather than focusing on educational factors associated with learning, motivation, and student identity (Ma & Nickerson, 2006 and Lowe, Newcombe & Stumpers, 2012). Ma & Nickerson (2006) have noted that engineering remote laboratories are growing in popularity because they allow college-level students to develop technical skills. Although there has been considerable research regarding students’ laboratory experiences in science education, there is a need to understand how students engage in learning with remote access technology in science education (Lowe, Newcombe, & Stumpers, 2012).

Remote learning environments offer unique learning experiences such as accessing novel research tools or communicating with scientists and researchers anywhere in the world. Students for the first time in history can become virtual researchers in an array of science laboratories. As a consequence of this access, the idea of *ownership of data* has emerged as a novel research focus because students are able to contribute, view, and analyze scientific data within remote learning environments and through other science endeavors such as citizen science projects (Catlin-Groves, 2012). However, there is a dearth of information in relation to student perceptions of ownership of data in science projects and remote learning systems. Ownership of data in in relation to virtual presence, student motivation to do science, and science identity could have significant implications for new ways to teach science education. Since scientific data sets are now becoming more accessible and students are able to contribute to the large body of knowledge, it is important for educators to understand the implications of students' ownership of data collected in remote and virtual investigations.

This study fills a gap that exists about the value of remote access technology; specifically, we need to know more about relationships among students' perception of data ownership, science motivation, science identity, perception of virtual presence, and learning outcomes. This study will:

1. Identify factors that contribute to successful remote learning investigations.
2. Document students' perception of ownership of data, science motivation, science identity, and learning outcomes during a remote technology learning investigation.
3. Document students' perception of virtual presence during a remote technology learning investigation.

Research Questions

The aim of this research study was to examine the relationship between students' perception of data ownership during a remote electron microscopy investigation program

(*Virtual Microscopy Lab*) and students' motivation, science identity, interest in science and entomology, and sustained motivation. In addition, this research study explored students' reported virtual presence and constraints and benefits of a remote learning environment. The specific research questions are addressed as follows:

RQ1. Is there a relationship between *perceived ownership of data* in a remote learning session and students' motivation to engage in science?

RQ1 Sub-question. Is there a relationship between *perceived ownership of data* in a remote learning session and students' sustained motivation to engage in science?

RQ2. Is there a relationship between *perceived ownership of data* in a remote learning session and students' science identity?

RQ3. What is the students' *perceived presence* (how *real* is it) during a remote access investigation?

RQ4. Does *Virtual Microscopy Lab* facilitate learning?

RQ5. What are the constraints and affordances of *Virtual Microscopy Lab*?

Traditionally, classrooms are teacher directed and the students are listeners who follow instructions and orders; however, remote learning environments can break the conventional teaching mold. Remote learning environments allow students to direct their learning goals, interact with scientists and research-grade tools through the Internet, and facilitate student directed collection and submission of data to scientific organizations. This novel technology may aid in addressing the concerns of the 21st century workforce to produce scientifically literate citizens by providing students in schools with real experiences and opportunities to learn science and technology with remote learning environments.

CHAPTER TWO

Review of the Related Literature

Remote Learning Environments

Remote learning environments have the potential to enable students to engage in authentic learning experiences that are important for learning science. Remote technology allows students and teachers to access real scientific tools too costly for classroom use (scanning electron microscopes, telescopes, etc.) and to communicate with scientists through a network connection (Ma & Nickerson, 2006; Lowe, Newcombe, Stumpers, 2012). During a remote investigation, students are able to develop experiments and engage in scientific inquiry: observe, question, collect and analyze data, and interpret results (Lowe, Newcombe, Stumpers, 2012). Remote learning environments have the potential to engage students in science in innovative ways since technology use in science classrooms has been shown to increase student interest in science as well in academic achievement overall (Walsh, Sun, & Riconscente, 2011; O'Day, 2007). Remote learning environments bridge the traditional gap between hands-on laboratories and computer simulations by providing students the opportunity to do real investigations at a distance from a scientific laboratory.

Although the implications for remote learning environments in middle school and high school could be significant for student interest in science and learning, research in such systems is severely limited in number and scope (Lowe, Newcombe, & Stumpers, 2012). Most of the existing literature describes the design and implementation of remote access technology rather than the efficacy of the technology (Ma & Nickerson, 2006; Lowe, Newcombe, & Stumpers, 2012). In addition, the remote access technology that is available is heavily biased towards engineering disciplines and college-level students (Ma & Nickerson, 2006; Ku, Ahfock, & Yusaf, 2011).

Although research in remote learning environments has been limited in scope and depth, there are a limited number of studies that investigate learning and student experiences in conjunction with remote access technology utilization in classrooms. Lowe, Newcombe, and Stumpers (2012) researched students' understanding of remote access technology in grades 9-11 located in Western Australia. Results from this investigation showed that students perceived remote access technology to be a valid practical experience in obtaining and reproducing data. However, students reported that remote access technology was less engaging than hands-on laboratories.

Jones, Andre, Kubasko, Bokinsky, Tretter, Negishi, Taylor, and Superfine (2003) investigated 209 high school and middle school students understanding of viruses using a remote atomic force microscope in conjunction with varying degrees of haptic experiences (full haptic experience touch and force feedback sensory information and haptic joystick receiving only tactile sensory responses). The study showed that there were significant gains from pre to post time periods for all students in relation to attitudes, knowledge of viruses, development of conceptual models, and understanding of scale. However, students that had the full haptic experience had significantly higher attitudes than the other groups, which may suggest that the overall haptic sensory experience may have been more engaging and motivating. Another related study conducted by Jones, Andre, Superfine, and Taylor (2003) studied fifty high school students' understanding of viruses utilizing a remote atomic force microscope and a haptic device in which students' knowledge of microscopy, scale, and knowledge of viruses changed as a result of the students' experiences. While the focus was on the haptic feedback devices, the researchers' suggest experiences with technology may be beneficial to students' engagement, motivation, and learning of science concepts.

In general, laboratories are essential to science education, as they offer real science experiences (Boud et al., 1986; Hofstein & Lunetta, 1982; Novak, 1976; Cloug, 2002). Currently, many laboratories have been transformed into computerized and simulated experiences, effectively changing how laboratory work is implemented in science courses (Scanlon, Morris, Paolo, & Cooper, 2002). However, debates emerge as to whether face-to-face laboratories are more conducive to science learning than simulated or remotely accessed laboratories. According to Corter, Esche, Chassapis, Ma & Nickerson (2011), there are mixed, complex results in interpreting the benefits of face-to-face, simulated, and remotely operated laboratories indicating that the effectiveness of simulated and remotely operated laboratories may be dependent upon "social and motivation factors" and how those new technologies are implemented in the course (p. 2063). According to Cooper et al. (2000), students are more motivated while using remote access laboratories, and the study found that remote access laboratories were more effective than simulations (Scanlon, Colwell, Cooper, & Paolo, 2004). However, most studies of remote access technology literature focused on student conceptual learning and professional skills as compared to hands on laboratories and simulations that emphasize conceptual, design, and professional skills (Ma & Nickerson, 2006).

The lack of research suggests there is a need to study the efficacy of remote learning environments with K-12 students. Understanding how students interact with remote learning environments is crucial for the development and maintenance of remote access technology educational programs which are growing in number. There are many factors that may contribute to the successful implementation of a remote learning environment including students' perceived level of **presence** (how *real* is the remote learning environment), students' **motivation** to do science, and students' perception of their **science identity**. These factors will be discussed below.

Virtual Presence

Presence is how *real* a virtual environment is perceived by an individual. There are numerous definitions and views of presence in research that span diverse academic disciplines such as psychology, computer science, and engineering (Lombard & Ditton, 2006). Presence is often subdivided into other related terms (physical, telepresence, and virtual) designed to describe an individual's experience (Sheridan, 1992; Ma & Nickerson, 2006; Lee, 2004). For the purpose of this study, *virtual presence* will be the focus since remote learning environments are mediated by Internet and network connections.

Several researchers have attempted to define the distinctive and important factors that contribute to presence. Sheridan (1992) defined presence as of participants' ability to feel physically present at a remote site through the engagement of the senses (level of realness), sensory control, and manipulability of the remote program. Another author defined presence as the general sense of being in an environment through a communicative medium (Steuer, 1992). Two main factors that contribute to a high level of presence are how *vivid* and *interactive* the communication medium is and the degree to which it allows engagement of participants. Lombard and Ditton (1997) described presence as a compilation of several factors (realism, transportation, immersion, social actor, medium, and social richness) that enable participants to have a high sense of engagement and *realness* which may alter their perception of reality.

Common to these ideas are control and sensory factors that influence the perception of virtual reality among participants. The model of presence that will be the focus in this study is Witmer and Singer's Conditions of Presence, which includes the participants' level of involvement, ability to focus, and the level of immersion or realness of the virtual environment (Witmer & Singer, 1998; Schifter, Ketelhut, & Nelson, 2012). These conditions for presence are influenced by four factors that govern participants' attention in a virtual reality context:

1. **Distractions** that may impede student perception of presence may originate from the external environment, such as interruptions from peers, or within the remote learning system such as interface technological problems.
2. **Sensory information** (auditory, visual, and tactile) that is generated output of information is process by the participant. Integrating sensory information may increase perception of presence.

3. **Control factors** in a remote learning environment that may include the ability to access and navigate the software efficiently or participants' ability to interact freely with the scientists.
4. **Perception of realism** is the extent to which participants feel as if they were located in the research lab instead of in the classroom. Vividness of the remote learning environment is crucial for the perception of presence.

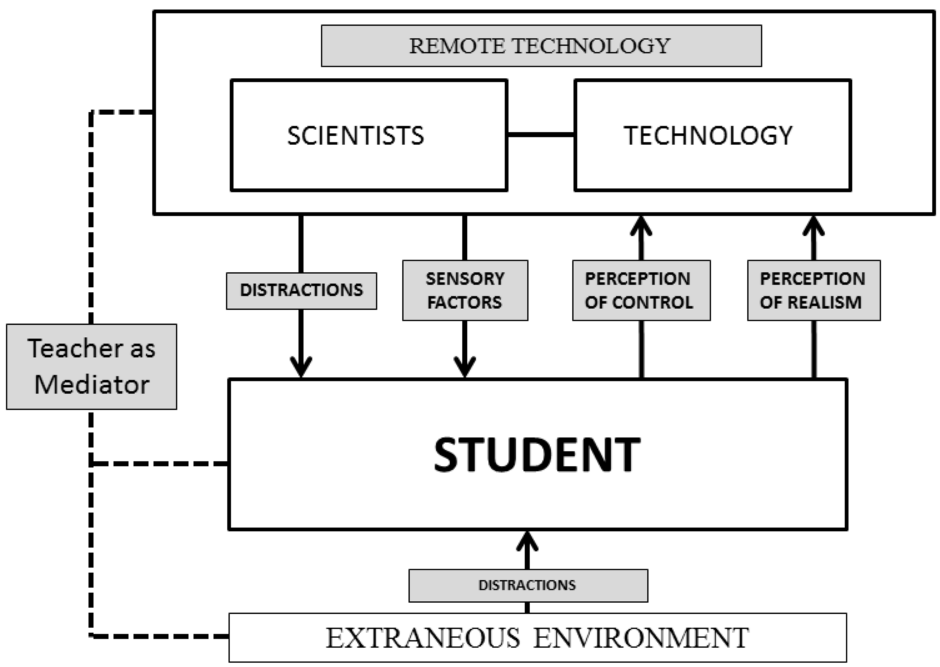


Figure 2.1. A model of the relationship of factors (distraction, sensory, control, realism) of presence in relation to the student and remote learning environment.

In this model, Figure 2.1 shows an interactive model of presence factors in a remote learning system in which the instructional technology is often mediated by a teacher or instructor to ensure an appropriate connection is established between the student and the remote learning environment. The remote learning environment typically consists of scientists and the relevant technology used to promote learning, motivation, and engagement.

Research on the relationship between presence and student learning and performance of tasks suggests that higher levels of perceived presence positively influence students' performance and learning objectives (Sheridan, 1992; Steuer, 1992; Slater & Usoh, 1993; Mikropoulou, 2006; Bystrom & Barfield, 1999; Barfield & Weghorst, 1993; Winn et al. 2002; Hedley et al., 2002). However, the link between presence and learning has been questioned by other researchers. Some researchers argue participants with a high level of perceived presence are already highly engaged within the learning environment (Scoresby & Shelton, 2009).

As noted above, participants that are engaged in remote learning environments may be affected by distraction, sensory, control, and realism factors that impede or enhance their learning experience. However, little is known about the role of presence within remote learning environments in an academic setting, since most research focused on simulated virtual laboratories. A focus on understanding the relationship of presence and motivation and science identity may provide insight into how to best structure remote access investigations.

Motivation

Motivation is an inner behavioral drive that enables individuals to achieve goals. The concept of motivation often defines behaviors as being intrinsic or extrinsic in nature. Intrinsic motivation describes individuals engaging in behaviors for their own personal interest and self-satisfaction, whereas individuals who are motivated by outside extrinsic factors, behavior is based on a separable outcome, such as rewards. (Eccles, Simpkins, & Davis-Kean, 2006; Deci & Ryan, 1985; Deci, Vallerand, Pelletier, & Ryan, 1991).

Self-determination theory (SDT) distinguishes between motivation behaviors by defining them as either self-determined (behaviors are endorsed by choice) or controlled (behaviors are controlled through compliance) (Deci, Vallerand, Pelletier, & Ryan, 1991; Deci & Ryan, 1991). Historically, extrinsic motivation was assumed to not be self-determined; however, research now indicates that there are different types of extrinsic motivation in which some motivation behaviors can be self-determined through the process of internalization (Deci, Vallerand, Pelletier, & Ryan, 1991, Deci & Ryan, 1985). Internalization describes the process of regulating and converting non-intrinsically motivated behaviors into inner motivation (Deci, Vallerand, Pelletier, & Ryan, 1991; Deci, Eghrari, Patrick, & Leone, 1994; Schafer, 1968). Internalizing motivation behaviors coupled with intrinsic motivation may promote student interest in learning (Deci, Vallerand, Pelletier, & Ryan, 1991).

SDT suggests that individuals have psychological innate needs to function and promote growth (Deci, Vallerand, Pelletier, & Ryan, 1991). The authors state that these psychological needs emphasize three characteristic components that compose motivation:

1. **Competence**: an individual's understanding and performance of goals or outcomes.
2. **Relatedness:** an individual's need to create a social connection with others.
3. **Autonomy:** an individual's need to regulate their own actions.

Self-determined individuals highly engaged in competence, relatedness, and autonomy factors in an activity will contribute to motivation and thus enhance individuals' performance on tasks.

Self-determined motivation has been associated with greater cognitive engagement, persistence to complete activities, career choices, and academic outcomes (Lavigne, Vallerand, & Miquelon, 2007; Deci, Vallerand, Pelletier, & Ryan, 1991; Hanrahan, 1998; Williams, Weiner, Markakis, Reeve, & Deci, 1994; Black and Deci, 2000). Recently, it has been proposed that educational games and other various software learning systems increase student interest and motivation (Ford, Wyeth, & Johnson, 2012; Argyriou, Sevaslidou, & Zafeiriou, 2010; Ting, 2010). However, there is little research on the connection between motivation and remote learning environments. Remote access technology enables students to utilize research-grade science tools and communicate with scientists. As a result, there are significant implications of SDT in remote learning environments in regards to students' feelings of autonomy, their sense of competence, and the students' ability to relate the scientists.

Science Identity

Students' science identity, according to Brickhouse (2001), is based upon the students' perception of who they are, degree of capability, and what they want to do with science. However, since it is argued that science is a social construct manifested by human activity, student science identity is molded by how culture and society view science (Aschbacher, Li, & Roth, 2010). Student participation in science classes and future science careers may be influenced by various societal and cultural factors (Aschbacher, Li, & Roth, 2010). In addition, social interactions of students with others, such as teachers, parents, and peers, may help students construct their identity and form their relationship to each group. Because "students are active participants and learners in many different communities of practice, in which they have formal and informal apprenticeship opportunities to learn the common language, contentions, rituals, stories and histories valued within each community," remote learning environments may be an extremely valuable community to influence students' perception of science identity (Aschbacher, Li, & Roth, 2010, p. 565).

There are varying definitions and influential factors that shape students' perceptions of identity. Gee (2000-2001) described four types of identity:

1. **Nature identity** describes factors of identity that an individual is unable to control (*e.g,*. sex).
2. **Institution identity** is given by an authority of an institution, such as identifying as a student at a university.

3. **Discursive identity** describes an individual's trait that is often defined or given power by interactions with other people; for example, to describe an individual as *thoughtful* is based on the interactions that individual has with others.
4. **Affinity identities** are molded by interactions or shared experiences with other individuals.

Brown, Reveles, & Kelley (2005) utilized the discursive identity framework to examine student discourse in science implying that identity "has the potential to influence scientific literacy development" (p. 798). Because remote learning environments often allow scientists and researchers to communicate with students, understanding the potential influences that remote learning environments have on students' perceived science identity may have huge implications on the delivery and learning of science in classrooms.

For this study, Carlone and Johnson's (2007) science identity framework will be used to explore students' perception of science identity in relation to remote learning environments. Carlone and Johnson's (2007) research focused primarily on minority females; however, the core influential factors of identity are relevant to students' experiences in classrooms. These include:

1. **Performance**: a student's ability to implement various scientific practices.
2. **Recognition:** the extent to which a student is recognized (by themselves or others) as being a *science person*.
3. **Competence:** a student's level of understanding of scientific principles.

These three factors contribute to understanding the importance of identity in relation to performance and learning in science because a remote learning environment exposes students to research-grade tools and scientists that would otherwise be unavailable. Remote learning may have unique implications on students forming science identities in classroom settings.

Ownership of Data

There is a lack of information detailing students' perceptions of ownership of data in science projects and remote learning systems in research. The few studies that exist often address other forms of *ownership* as it pertains to education and learning. For instance, the research available often addresses student perception of ownership under the following circumstances: student perception of ownership and classroom structure, project ownership, business ownership and entrepreneurship, and students' perception of ownership and intellectual property rights in entrepreneurship capstone classes (O'Neill, 2010; Hanauer, Frederick, Fotinakes, & Strobel, 2012; Van Auken, 2013; Silvernagel, Schultz, Moser, & Aune, 2009).

O'Neill and Barton (2010) qualitatively investigated properties of students' *ownership* of learning throughout a science video project. Through an ethnographic lens, the researchers analyzed semi-structured student interviews, observations, and student work and found patterns in the data that revealed themes related to *ownership*. These include:

1. **How students positively represent themselves**: *Do students view themselves as scientists or teachers*?

2. **Purposeful utilization of appropriate materials and resources, time, and peer interactions:** *Do students use their time, group members, and time wisely?*

3. **Expression of pride in science:** *Are students proud of their achievements in science-related projects?*

4. **Agency:** *Does the science-related project help induce positive change for students' personally and socially?*

5. **Expression of positivity for science:** *Are the students' views of science positive?*

These studies suggest that while the concept of *ownership* is complex, student perception of control over what they learn is crucial for learning and engagement (O'Neill & Barton, 2010). Students' perception of *ownership of data* in a remote learning session may have implications for students' motivation and science identity within science classrooms.

Model of Remote Learning Environments

Discussion of the frameworks reviewed thus far (conditions of presence, self-determination theory, and science identity) are unified here into a working model for examining remote learning environments. This model shows the connections between these frameworks, particularly the hypothesized associations between the factors that comprise each framework. Collectively, this model allows for the examination of important parameters of remote learning environments that may support learning in science contexts.

Self-determination theory and the construct of science identity share similar characteristics that define how participants identify with science and are motivated to do science. Student perception of ownership may be tied to participants' motivation and identity.

Solid lines in Figure 2.2 indicate a hypothesized, direct, strong relationship between factors, whereas a dotted line suggests a weaker, yet important link between two factors.

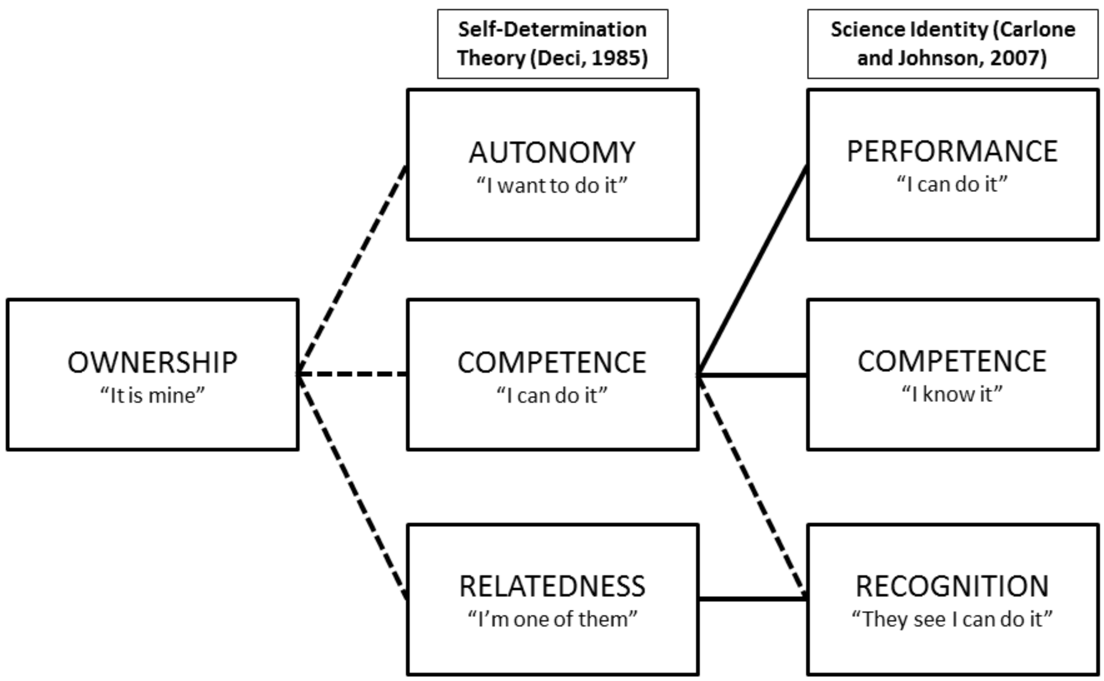


Figure 2.2. The hypothesized relationship of self-determination and science identity factors that relate to student perception of ownership of data.

Students' perception of ownership of data, translated into "it is mine," may affect students' motivation to do science and ultimately shape students' perceived notion of science identity. Students may feel empowered if they collect and control data in a science classroom setting. This empowerment may stimulate the need for students to be *autonomous* by self-directing their learning which may foster a sense of *competence* of accomplishment when engaged in scientific activities. Because students are actively engaged in collection and dissemination of data (a fundamental characteristic of research and scientific inquiry), students may develop a sense of *relatedness* with scientists and researchers. This perception may inspire students to continue to pursue scientific endeavors. Sustained motivation in science over time may influence students' perception of their identity. Students' awareness of *performance* and *competence* within science classrooms may influence how others *recognize* the students' scientific ability and aptitude, promoting continued interest in learning science. Remote learning environments can enable students' to develop a sense of data ownership and establish a connection with scientists which may advance students' interest and motivation in science and influence their identity.

Depicted below, the Model of Remote Learning Environments in Figure 2.3 developed for this study displays the hypothesized connections between the student and remote learning environment. Depending on the structure of the science instruction and the classroom setting, teachers can either have a dominant or passive role in remote learning environments by limiting or controlling student interactions with the science tools and/or the communication with the scientists. Distractions can hinder students' ability to interface with learning in remote environments and can originate from different sources usually perpetuated by the external environment (does not include the remote learning environment), such as inappropriate peer interactions during a remote investigation or an interruption of the classroom setting (i.e. fire drill). Distractions can also originate from the technology or the Internet connection. An additional internal environment distraction could be derived from the communication with the scientists. For example, the scientists may not be able to effectively communicate with the students (such as overly using technical terms without explanations) or scientists may not appropriately engage in a positive manner with students (cutting student dialogue off or not answering questions).

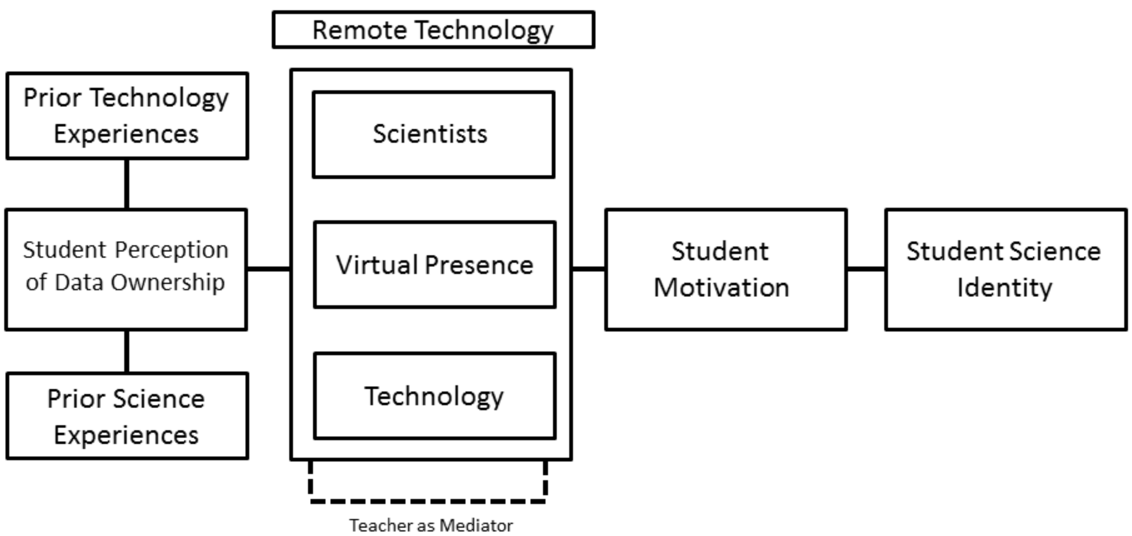


Figure 2.3. A hypothesized model of presence, self-determination, and science identity in the remote learning environment.

Multiple remote learning sessions along with students' perception of the use of their data may stimulate student interest in science and technology, sustain motivation, and alter students' perception of identity in science.

CHAPTER THREE

Methodology

Overview

This chapter describes the research methodology used to answer the following research questions:

RQ1. Is there a relationship between *perceived ownership of data* in a remote learning session and students' motivation to engage in science?

RQ1 Sub-question. Is there a relationship between *perceived ownership of data* in a remote learning session and students' sustained motivation to engage in science?

RQ2. Is there a relationship between *perceived ownership of data* in a remote learning session and students' science identity?

RQ3. What is the students' *perceived presence* (how *real* is it) during a remote access investigation?

RQ4. Does *Virtual Microscopy Lab* facilitate learning?

RQ5. What are the constraints and affordances of *Virtual Microscopy Lab*?

In the sections that follow the research design, participant selection, and the study site characteristics are described. A detailed description of the remote access program (*Virtual Microscopy Lab*) and the user interface utilized in the study are provided. Furthermore, details of the data collection instruments and assessments, including reliability and validity information are presented. Lastly, the procedural details of the study are provided.

Research Design

The study consisted of quantitative and qualitative measures to explore participants' perceived presence, ownership of data, science identity, motivation to do science, learning outcomes, previous experience with technologies, and sustained motivation during and after a remote learning session. Participating science classes in an urban high school located in the southeastern United States were randomly assigned to one of two groups. Both groups experienced the same remote learning technology, *Virtual Microscopy Lab*, which is described in detail below. Students in the experimental and control groups were divided into smaller cohorts consisting of approximately three students. Each cohort of students in the experimental group chose a *Drosophila melanogaster* (fruit fly) specimen (named hereafter as "cohort insect") that was viewed during the first remote learning session. The control group did not have the opportunity to choose a *Drosophila melanogaster* specimen. The control group viewed the experimental groups' *Drosophila melanogaster* specimens during the first remote learning session, but they were not informed that the *Drosophila melanogaster* specimens were collected by the experimental group. Both the control and experimental group participated in a second remote learning session that enabled the participants to view various types of insects provided by the *Virtual Microscopy Lab* scientists. Both session one (*Drosophila melanogaster* viewing) and session two (variety of insects viewing) lasted for approximately 45 minutes. Figures 3.1 and 3.2 below depict the design of the study, including the intervals at which assessments were given, and the research design notation.

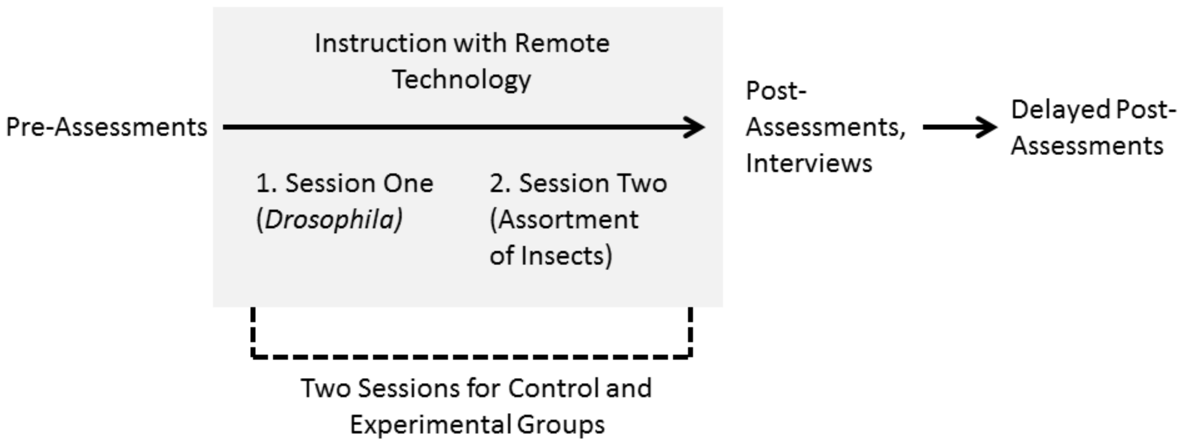


Figure 3.1 Study design depicting the two remote learning sessions for the control and experimental groups and incorporating pre-assessments, post-assessments and interviews, and delayed post-assessment.

Campbell and Stanley (1966) Research Design Notation

Survey Design (Pre, Post, and Delayed): O_1 X_1 X_2 O_2 O_3

Interview Design: X_1 X_2 O

Figure 3.2 Depiction of the research design notation as described by Campbell and Stanley (1966).

The survey design consisted of a pre survey before the two remote learning sessions and a post and delayed post survey after the two remote learning sessions. The interviews with teachers and students were conducted after the two remote learning sessions.

Table 3.1

Data sources (surveys, interviews, delayed assessment, and learning outcomes assessment) and related research questions

	Pre and Post Surveys	Student Interview	Delayed Post Survey	Pre and Post Learning Outcomes Assessment	Teacher Interview
RQ1: Motivation	X	X	X		
RQ2: Science Identity	X	X	X		
RQ3: Presence	X	X	X		
RQ4: Learning Outcomes				X	
RQ5: Benefits and Constraints	X	X	X		X

The table above shows the data sources (surveys and interviews) with the corresponding research questions.

Study Site and Participants

The study was conducted at an urban high school in the southeastern United States. The high school has approximately 200 students enrolled in grades nine through twelve with 46% of the population qualified for free/reduced lunch. The participants (n = 72) were obtained from 6 of the 9 ninth and tenth grade biology and physical science classes. This sample was comprised of 29 males (41%) and 43 females (59%). The ethnic composition of the students in the study consisted of 1.4% American Indian, 2.8% Asian, 73.2% African

American, 11.3% Caucasian, 1.4% Hispanic, and 9.9% identified as *other*. This ethnic breakdown is consistent with the general population in the area the school is located (U.S. Census Bureau, 2014). The six classes were randomly assigned to the control (n = 36) or the experimental group (n = 36). The study was approved by the North Carolina State University Institutional Review Board located in Raleigh, North Carolina and the Review Board of the school system. Consent to participate in the study was given by the participants and their parent or guardian to collect survey and interview data.

Instructional Technology

Virtual Microscopy Lab (a pseudonym) is a remote electron microscopy program hosted by a University located in the Midwest of the United States. Since 1999, *Virtual Microscopy Lab* has conducted over 300 sessions to formal and informal educational groups to educate participants about microscopes and insects ("*Virtual Microscopy Lab*," 2010). Participants collect insects and send the insects through the mail to the *Virtual Microscopy Lab* scientists at the University. The insects are mounted on a stage by the scientists and are viewed with a scanning electron microscope.

The web-based *Virtual Microscopy Lab* program allows participants to view the specimen, change the focus and magnification, and communicate with the scientists in real-time through an online interactive chat module (shown in Figure 3.3), to direct the scanning electron microscope to view a chosen insect and manipulate the image (shown in Figure 3.4 and Figure 3.5), and to view the participants in the group (shown in Figure 3.6).

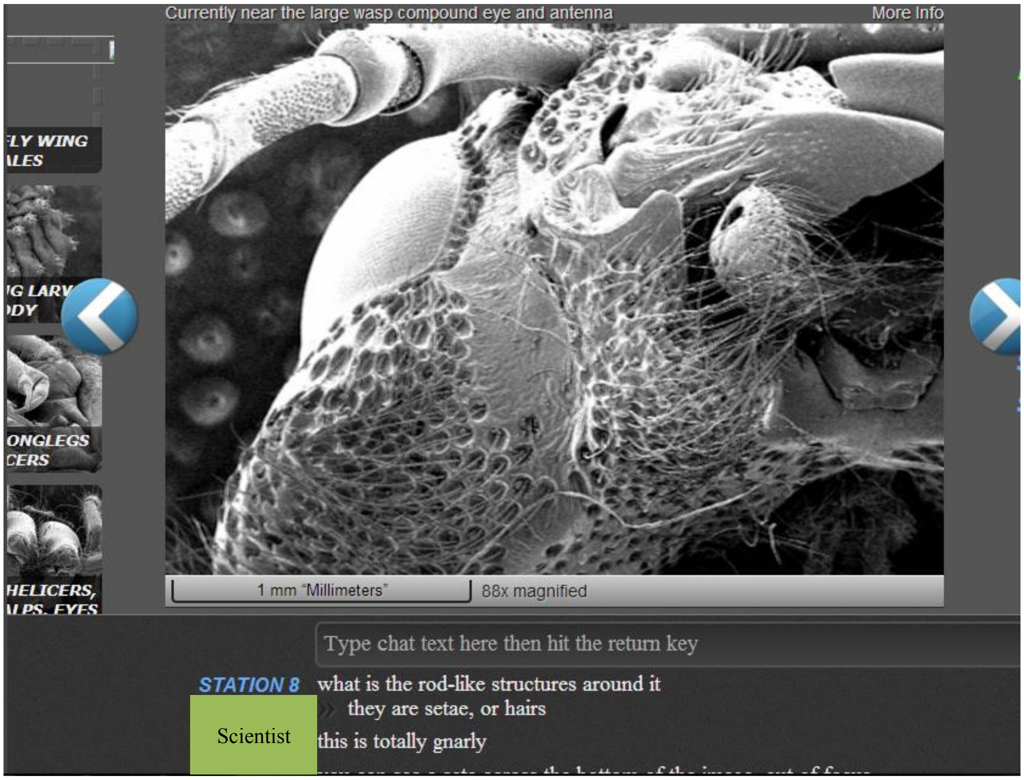


Figure 3.3 Screenshot of the main *Virtual Microscopy Lab* interactive session screen.

The user interface on the main page of the *Virtual Microscopy Lab* has several interactive components for teachers and students. The selected insect is displayed prominently in the middle of the screen. At the top of the insect image, a brief heading displays a general description of what the students are viewing. The bottom of the image displays size and magnification for each image. Below the image, students are able to type in questions or comments to the scientists. In Figure 3.3 above, "Station 8" was a group of students in the study that asked about the structures they were viewing on the main screen; "Scientist 1" and "Scientist 2" were the scientists supplying information and answering questions to the students. To change the interface pages (described below) a blue control button with a white arrow located on the periphery of the webpage will allow students to maneuver between webpages within the user interface *Virtual Microscopy Lab* module.

Figure 3.4 Screenshot of the upper portion of the *Virtual Microscopy Lab* user interface if the student(s) have control of the scanning electron microscope.

As shown in Figure 3.4 above, if students are granted control by the *Virtual Microscopy Lab* scientists, a set of user control appear above the insect image. Students are able to change the magnification, focus, contrast, and brightness of the insect images. Control of the scanning electron microscope is granted by the scientists to each group. If a student does not have control, the user control bar is not displayed (as shown in Figure 3.3).

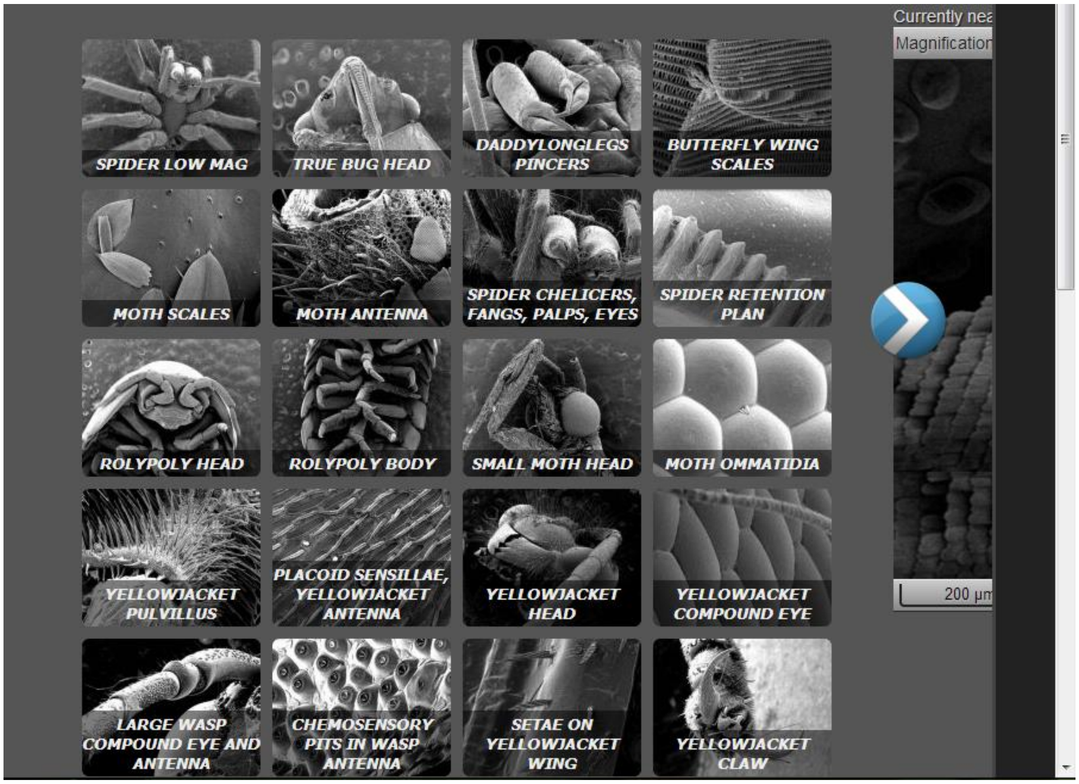


Figure 3.5 Screenshot of the user interface section that allowed students to choose an insect to view.

In Figure 3.5, the user interface displays insects that students can view. The student moves his or her mouse cursor over the selection, left clicks with the mouse, and the insect selection appears on the main page for the students to view. The insect images were pre-uploaded by the *Virtual Microscopy Lab* scientists before the remote learning session was initiated with the students. In Figure 3.6 below, this user interface menu allows students, teachers, and the scientists to view the participants logged on for the remote learning session.

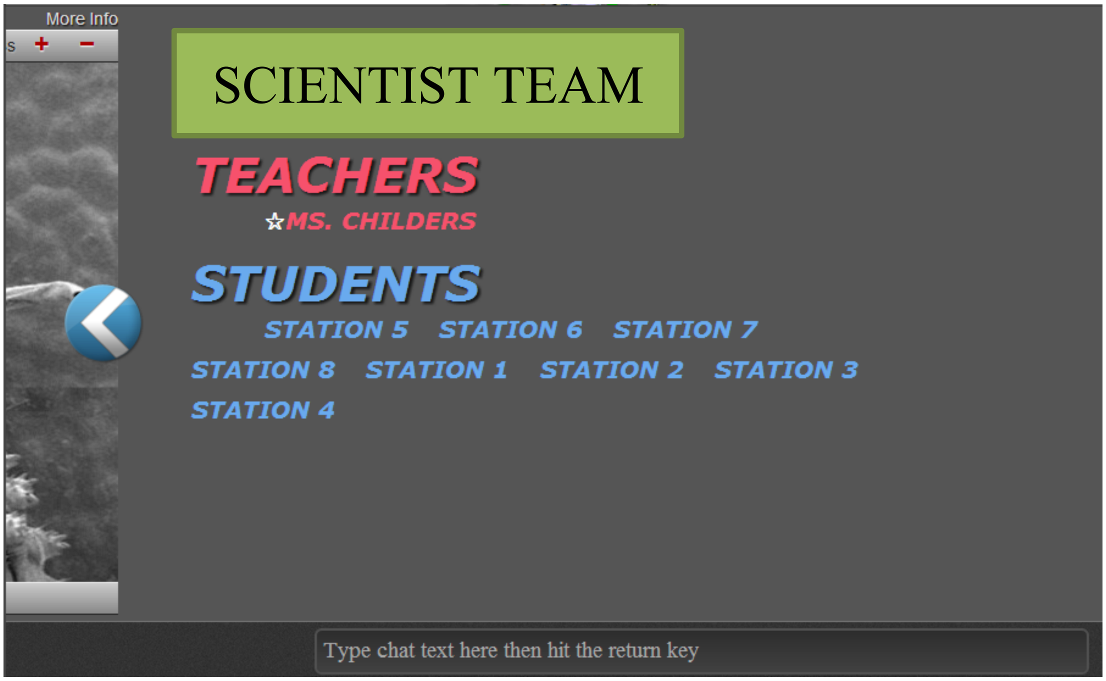


Figure 3.6 Screenshot of the user interface participant menu.

Each student in a cohort (experimental and control groups) was given the opportunity to control the scanning electron microscope by selecting the specimen that he or she wanted to view, change the magnification, or “drive” the electron microscope by moving the camera around the image. Throughout the investigations, students explored how scanning electron microscopes operate, the form and function of insect body parts, and size and scale concepts in relation to electron microscopy.

Assessments

Assessments included a pre-post survey, a delayed post-survey, and an interview protocol for students and teachers (described below). These assessments were selected to assess if there was a relationship between participants' perception of degree of ownership and student motivation, science identity, and perceived presence over the course of two remote access investigations with *Virtual Microscopy Lab*. An assessment developed to measure a student's knowledge of scanning electron microscopes and entomology was utilized to determine learning outcomes as a result of access to remote learning sessions. Student interview protocol questions were designed to understand participants' perception of their ownership of data, science motivation, science identity, and presence during the remote learning session. The teacher interview protocol focused on teachers' perception of the benefits and constraints of using a remote learning system in the classroom. A delayed post-survey investigated students' sustained motivation in science such as continued interest in microscopes and entomology. A description of the assessments is listed below:

1. The **Learning Outcomes Assessment** contained questions designed to capture participants' understanding of scanning electron microscopes and basic entomology principles. The items were reviewed by a panel of four science educators and an entomologist. Items assessed ideas such as "What are the major body parts of insects?" and "How do scanning electron microscopes function?" Cronbach's Alpha was calculated with the participating students of a reliability value of .72. Values higher than .70 are often considered acceptable reliability (McDonald, 1999).

2. The **Presence Survey** is a modified Condition of Presence Survey developed by Witmer and Singer (1998). The survey items were modified to specifically address presence factors during a *Virtual Microscopy Lab* investigation. The survey contains questions designed to

understand the participants' perceived presence during a remote access investigation by recording participants' perception of the four presence factors: sensory, distraction, realism, and control after they complete a remote access investigation. Student responses to the Likert items were on a scale from 1 to 6 (strongly disagree to strongly agree). Cronbach's Alpha was calculated with a reliability value of .87.

3. The **Motivation Survey** and **Delayed Motivation Survey** were adapted from Glynn's (2010) Science Motivation Questionnaire II. Survey questions were modified to address students' motivation to do science in a remote investigation and motivation to learn about insects. The survey assesses participants' perceptions of their intrinsic motivation and self-determination before and after a remote access investigation. Self-determination factors included within the survey questions including competence, relatedness, and autonomy. Student responses to the Likert items were on a scale from 1 to 6 (strongly disagree to strongly agree). Cronbach's Alpha was calculated with a reliability value of .90.

4. The **Science Identity Survey** is an adaptation of the Maximizing the Impact of STEM Outreach (MISO) survey and Williams, George-Jackson, Baber, and Trent's (2011) Science Identity survey that contains questions that document participants' perceived ownership of data, competence, performance, and recognition in science. Survey items were modified to address students' perceptions of science identity in relation to student interest in insects and remote investigations. Student responses to the Likert items were on a scale from 1 to 6 (strongly disagree to strongly agree). Cronbach's Alpha was calculated with a reliability value of .89.

5. The **Student Interview Protocol** included open-ended questions that were designed to understand participants' sense of presence during a remote investigation, motivation factors to do science, science identity, and ownership of data. After a thorough read of the answers by the students, a set of codes was developed for each question. A frequency count of answers for each question was recorded.

6. The **Teacher Interview Protocol** included open-ended questions that were designed to understand teachers' perceptions of the benefits and constraints of using remote technology in a classroom setting. After a review of the answers by the teachers, a set of codes was developed for each question. A frequency count of answers for each question was recorded.

7. **Prior Technology Experience Survey** determined the students' access and experiences with technologies that relate to remote investigations and data ownership. Students were asked to state *yes* or *no* if they had daily access to a computer and Internet. Next, technology items were listed in which the student had to select at which level they had access based on a 4 point scale (never, rarely, sometimes, always).

8. **Prior and Post Experiences with Insects** determined the students' experiences before and after a remote investigation. Students were asked to state *yes* or *no* to questions that addressed prior experiences with insects.

Table 3.2

Assessment items on surveys that relate to constructs of presence, motivation, science identity, and perceived ownership

Construct	Survey Item
Presence	
a. Sensory Factor	"My sense of sight was highly engaged when participating in *Virtual Microscopy Lab* session."
	"My sense of touch was highly engaged with participating in *Virtual Microscopy Lab* session."
b. Distraction Factor	"When participating in *Virtual Microscopy Lab* session, I was aware of other events occurring around me."
	"I can concentrate easily while participating in *Virtual Microscopy Lab* session."
c. Realism Factor	"I lost track of time when participating in *Virtual Microscopy Lab* session."
	"I was easily distracted when participating in *Virtual Microscopy Lab* session."
d. Control Factor	"I was able to move around in *Virtual Microscopy Lab* session with ease."
	"I can easily manipulate *Virtual Microscopy Lab* session in any way I want."
Motivation (Self-Determination)	
a. Intrinsic Factors	"Learning about science is interesting."
	"Learning science makes my life more meaningful."
b. Autonomy	"I feel obligated to work on this online science project."
	"I have a choice in choosing what I want to learn during the *Virtual Microscopy Lab* session."
c. Competence	"I use strategies to learn science well."
	"I study hard to learn science."
d. Relatedness	"I feel I am able to interact freely with the scientists."
	"The scientists encouraged me to explore the activities in *Virtual Microscopy Lab* session."
Science Identity	
a. Performance	"I expect to do well in science class this year."
	"I could easily use the *Virtual Microscopy Lab* tools to view the insect."
b. Competence	"I feel confident that I can learn a lot about insects while using the *Virtual Microscopy Lab* program."
	"I can do advanced work in science."
c. Relatedness	"It is important to me that others see me as a scientist."
	"I can relate to the *Virtual Microscopy Lab* scientists."
Perceived Ownership of Data	
a. Ownership	"After the *Virtual Microscopy Lab* session, who do you feel should keep the insect?"
	"Was it more interesting to look at your insect or someone else's insect?"

Procedural Protocol

Participants in the control and experimental group were introduced the study and the *Virtual Microscopy Lab* program four weeks prior to the remote learning session. Table 3.3 details the outline of events in the study.

Table 3.3

Research timeline of events during the remote learning study

	Introduction of Study	Collection and Submission of Insects	Pre Survey	Two 45 minute Remote Learning Sessions	Post Surveys	Student and Teacher Interviews	Delayed Post Survey
Four Weeks Prior to Remote Access Investigation	X						
Two Weeks Prior to Remote Access Investigation		X					
One Week Prior to Remote Access Investigation			X				
Week of Remote Access Investigation				X	X	X	
Five Weeks After Remote Access Investigation							X

Prior to instruction, participants were given an overview of events, what an electron microscope looked like, how remote access technology works, and the connection of that technology with the electron microscope, as well as the participants will view insects with the technology. Learning concepts included on the pre and post learning assessment were not introduced at this time. A consent form was sent home with participants and their parents to sign.

Once consent forms were returned by participants, the students in the experimental classes were assigned to a cohort consisting of 3 participants. Each cohort was given lab supplies and was asked to choose a *Drosophila melanogaster* specimen to view with an electron microscope. The lab supplies for each group consisted of goggles, tweezers, magnifying glasses, ethanol contained in a glass vial, white paper, and *Drosophila melanogaster*. Before the selection and collection of the *Drosophila melanogaster* specimen, participants reviewed lab safety procedures. Participants in each group were instructed to place the *Drosophila melanogaster* on a white sheet of paper in order to view the specimens easily. Once the *Drosophila melanogaster* specimens were placed on a white sheet of paper, participants were then instructed to use a magnifying glass and select the best specimen for their group to view with the electron microscope, as shown in Figure 3.7.

Figure 3.7 Students collecting a *Drosophila melanogaster* specimen.

After the groups selected their specimen, the *Drosophila melanogaster* was carefully transferred to a glass vial full of ethanol by tweezers. Participants labeled the glass vial with the school's name, group number, and date of collection. The instructor packaged and mailed the insects to the scientists to prep the insects for the remote investigation.

Participants completed the pre-assessments (learning outcomes assessment, motivation survey, science identity survey, and technology experience survey) before engaging in the first remote technology investigation with *Virtual Microscopy Lab*. After the submission of insects to the University and the completion of the pre-assessments, participants interacted with the remote access technology tool, *Virtual Microscopy Lab* in the school's computer lab. During the first forty-five minute remote investigation session, the scientists at the University projected the scanning electron microscope feed through the Internet which allowed participants to adjust the magnification and focus on the image of the *Drosophila melanogaster* specimens. The instructor located in the computer lab with the students projected guiding questions on a board in the computer lab to help direct the participants throughout their remote investigation and learning. Guiding questions included the following:

1. **Where are the body segments located on the specimen?**
2. **What is the magnification of the insect image you are viewing?**
3. **What is the function of the insect part you are viewing?**

Participants were able to ask the researchers operating the scanning electron microscope additional questions about microscopy and insects during the laboratory experience in real-time. In addition, each participant in all cohort groups in both the control and experimental groups were allowed to control the scanning electron microscope. Every group had approximately five minutes to view the specimens of their choice on the screen. During the five minute control of the scanning electron microscope, all students in the group had to manipulate the settings while viewing the specimen. All participants were able to view selected images by the group that was in control.

During the second forty-five minute remote investigation session, the scientists at the University projected the scanning electron microscope feed through the Internet which allowed participants to adjust the magnification and focus on the images of the different insect specimens (which were provided by the researchers at the University projected by the scanning electron microscope).

Participants were able to ask the researchers operating the scanning electron microscope additional questions about microscopy and insects during the laboratory experience in real-time. In addition, each participant group in both the control and experimental groups were allowed to control the scanning electron microscope for approximately five minutes to view the specimen on the screen.

Once the participants completed the *Virtual Microscopy Lab* program that included the two remote learning sessions, the following post-assessments were completed: learning outcomes assessment, presence survey, motivation survey, and science identity survey. Five control students and five experimental students were randomly chosen to participate in the post-interviews. Five weeks after the completion of the module, the participants completed the delayed post survey to determine if the remote investigation promoted sustained motivation in science.

Limitations

The study was conducted in an urban school with high numbers of underrepresented students with low socio-economic standing and involved only two classes.

Care should be taken before generalizing the results to other school contexts due to the specific context of this study that involved an urban school with high numbers of underrepresented students with low socio-economic standing and limited numbers of participants. Additionally, although each student in the experimental and control group had the opportunity to control the scanning electron microscope remotely, students worked in groups. The degree to which there was a group effect on students' experiences is not known. Furthermore, some students in the interviews reported having had regular experiences with insects that did not fall under the scope of the *prior interests with insects* survey constructs. it is not clear how those prior exposures man have influenced results.

CHAPTER FOUR

Analysis

Overview

The first section describes the analyses of the data for the control and experimental group. This is followed by a description of the analyses of the assessments for the treatment and control groups by research questions.

Establishing Similarity of Prior Technology and Insect Experiences

Student responses to the *Prior Technology Experiences* and *Prior Insect Experiences* survey were recorded before the remote investigation. Descriptive statistics for the *Prior Technology Experiences* and *Prior Insect Experiences* surveys were calculated.

Similarity of Prior Technology Experiences. Students were asked to state *yes* or *no* if they had daily access to a computer and the Internet. Next, technology items were listed in which the student had to select the level of their technology use based on a 4-point scale (Never, Rarely, Sometimes, Always). A Fisher's Exact Test (two-tailed, alpha = .05) was tested to determine if there was significantly different association between the experimental and control groups of daily access to a computer and Internet. The students' survey scores for the technology items were compared across the treatment groups using the Mann-Whitney U test (two-tailed, alpha = .05).

Similarity of Prior Insect Experiences. The students' survey scores for the *Prior Insect Experiences* items were compared across the treatment groups using a chi-square test for independence to determine if there were differences in the control and treatment groups.

Research Question 1. Is there a relationship between students' *perceived ownership of data* in a remote learning session and students' motivation to engage in science?

Motivation Survey

Student responses to the Likert items on a scale from 1-6 (strongly disagree to strongly agree) on the *Motivation Survey* were recorded during the pretest, posttest, and delayed posttest sessions.

Similarity of Perceived Motivation to do Science. The *Motivation Survey* was administered before the remote investigation to determine if students in both groups reported similar motivation to do science. The students' pretest motivation scores were compared across treatment groups using a Mann-Whitney (two-tailed, alpha = .05) test.

Ownership of Data and Students' Motivation to do Science. Students' posttest motivation scores were compared across the treatment groups using the Mann-Whitney U test (two-tailed, alpha = .05) to determine if the experimental group that selected their own insect had different reported motivation to do science than the control group (that did not select their own insect).

Remote Investigations on Students' Motivation to do Science. The students' pretest and posttest motivation scores were compared by treatment group to determine if there were changes in motivation as a result of doing the remote investigation. The control group and experimental pretest and posttest motivation scores were analyzed using the Wilcoxon Signed-Rank test (two-tailed, alpha = .05).

Research Sub-question 1. Is there a relationship between students' *perceived ownership of data* in a remote learning session and students' sustained motivation to engage in science?

Delayed Motivation Survey

Motivation Over Time. The students' pretest, posttest, and delayed posttest motivation scores were compared across groups to determine if there was sustained motivation to do science after the remote investigation. The control and experimental groups' pretest, posttest, and delayed motivation scores were analyzed using the Friedman Test (alpha = .05) with Wilcoxon Signed Rank post hoc tests (two-tailed, alpha = .05).

Research Question 2. Is there a relationship between students' *perceived ownership of data* in a remote learning session and students' science identity?

Science Identity Survey

Students' Likert scores 1-6 (strongly disagree to strongly agree) on the *Science Identity Survey* were analyzed pre and post to the remote investigation.

Similarity of Perceived Science Identity. The students' pretest science identity scores were compared across treatment groups using a Mann-Whitney (two-tailed, alpha = .05) test.

Influence of Ownership on Students' Perception Science Identity. Posttest science identity scores were compared across the treatment groups using the Mann-Whitney U test (two-tailed, alpha = .05) to determine if there were more changes in science identity for the experimental group than the control group.

Influence of Remote Investigations on Students' Perception of Science Identity. The students' pretest and posttest science identity scores were compared pre to post for the control group and the experimental group to determine if science identity perception changed after the remote investigation. The control group and experimental pretest and posttest science identity scores were analyzed using the Wilcoxon Signed-Rank test (two-tailed, alpha = .05).

Research Question 3. What are students' *perceived presence* (how *real* is it) during a remote access investigation?

Presence Survey

Student responses to the Likert items on a scale from 1-6 (strongly disagree to strongly agree) on the *Presence Survey* were recorded after the students completed the remote investigation. The *Presence Survey* statements were analyzed by item and by construct.

Ownership of Data Influence by Construct. The students' *Presence Survey* construct scores were compared across the treatment groups using the Mann-Whitney U test (two-tailed, alpha = .05) to determine if the experimental group experienced different perceptions of virtual presence than the control group.

Ownership of Data Influence by Item. All *Presence Survey* items were compared across treatment groups using the Mann-Whitney U test (two-tailed, alpha = .05).

Research Question 4. Does *Virtual Microscopy Lab* facilitate learning?

Learning Outcomes Assessment

Student responses to the items on the *Learning Outcomes Assessment* pretest and posttest were scored for accuracy.

Establishing normality. The means and standard deviations of the pretest and posttest scores were calculated as well as an assessment of normality of the score distributions by calculating the Shapiro-Wilk statistic.

Similarity of Initial Knowledge Level. An independent *t-test* (two-tailed, alpha = .05) was used to compare the pretest scores of the control and experimental group to determine if the experimental and the control group entered the study with a similar level of knowledge on insects.

Ownership of Data Learning Influence. The students' posttest scores were compared across the treatment groups using the Mann-Whitney U test (two-tailed, alpha = .05) to determine if there were differences in the experimental group (that selected their own insect) and the control group.

Remote Investigation Learning Influence. The students' pretest and posttest scores were compared for each group (experimental and control) to determine if learning occurred after the remote investigation. The control group and experimental pretest and posttest scores were analyzed using the Wilcoxon Signed-Rank test (two-tailed, alpha = .05). The Wilcoxon Signed-Rank test was implemented to compare the pretest and posttest scores of the experimental group because the posttest scores were not normally distributed.

Research Question 5. What are the constraints and affordances of *Virtual Microscopy Lab*?

Interest in Insects

Student responses to the Likert items on the *Interest in Insects* assessment were recorded during the pretest, posttest, and delayed posttest sessions.

Similarity of Interest in Insects. Pretest interest in insect scores were compared across treatment groups using a Mann-Whitney (two-tailed, alpha = .05) test.

Influence of Ownership on Students' Interest in Insects. The students' posttest interest in insects score were compared across the treatment groups using the Mann-Whitney U test (two-tailed, alpha = .05) to determine if the experimental group scores were significantly different from the scores of the control group.

Interest in Insects Over Time. The students' pretest, posttest, and delayed posttest interest scores were compared across groups to determine if there was a change in interest of insects over time after the remote investigation. The control group and experimental pretest, posttest, and delayed motivation scores were analyzed using the Friedman Test (alpha = .05) with Wilcoxon Signed Rank post hoc tests.

Post Interest in Insect Experiences

A chi-square test for independence was used to determine if there was significantly different association between the experimental and control groups post interest in insect experiences (however, student answers that resulted in *maybe* were not included in the chi-square test for independence analysis). Percentages for each item and frequency count are reported for the entire sample.

Remote Learning Environment Model

A proposed *Remote Learning Model*, based on the review of literature on the topics of remote investigations, virtual presence, motivation, and science identity was developed for this study. This model was used as part of the analyses to explore whether there are relationships among the components of motivation to do science, virtual presence, and science identity (Figure 4.1).

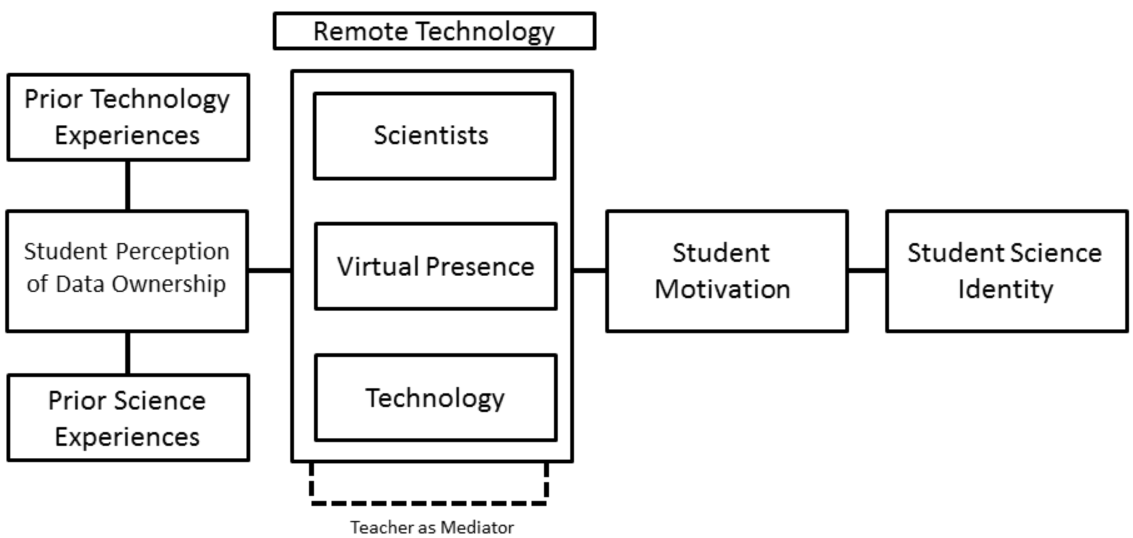


Figure 4.1. A hypothesized model of presence, self-determination, and science identity in the remote learning environment.

Correlations between the Constructs in the Remote Learning Environment Model. To measure the strength and direction of association of the constructs in the *Remote Learning Environment* a Spearman rank-order correlation coefficient (two-tailed, alpha = .05) was calculated for the experimental and control groups. An additional variable, *Interest in Insects,* was added based on the responses on the interest item given during the pretest, posttest, and delayed posttest and the assumption that interest in insects may alter students' perceptions during the course of the study.

Exploring the Relationships between Factors within each Construct. To measure the strength and direction of association of the factors within the constructs in the *Remote Learning Environment* a Spearman rank-order correlation coefficient (two-tailed, alpha = .05) was calculated for the experimental and control groups.

Factor Analysis of the Constructs for the Remote Learning Environment. Because there were several variables identified in the *Remote Learning Model*, an exploratory factor analysis was used to identify the variables that contribute to remote investigations. Thirteen identified variables relating to remote investigations were factor analyzed using the principal component analysis of extraction utilizing the Varimax rotating method.

Influence of Ownership on Science Learning Drive, Environmental Presence, and Inner Realism Presence. The constructs that emerged from exploratory factor analysis scores were compared across the treatment groups using the Mann-Whitney U test (two-tailed, alpha = .05) to determine if the experimental group scores were significant different from the control group scores.

Teacher Interviews

The three teachers (identified here as *Teacher 1, Teacher 2, and Teacher 3*) of the classes that participated in the study were individually interviewed after the *Virtual Microscopy Lab* sessions to understand the benefits and constraints of using remote technology to teach science in high school. All three teachers attended the two remote sessions for each of their classes. The three teachers were female. Teacher 1 taught chemistry and physics for over 20 years; Teacher 2 taught biology for 15 years, and Teacher 3 taught biology for 5 years. Each interview, approximately 10 minutes in length, was audio recorded, transcribed, and reviewed. The teachers' responses were summarized by question.

Student Interviews

Ten students (5 control; 5 experimental) were randomly selected and interviewed after the *Virtual Microscopy Lab* session to understand the benefits and constraints of using remote technology to teach science to students in high school. Additionally, questions pertaining to *ownership of data* were asked of participants in each group to understand the influences of choosing your insect versus not choosing your own insect for the remote investigation. There were two females and three male students interviewed from the control group and three females and two males interviewed from the experimental group. Interviews were approximately 15 minutes and were audio recorded, transcribed, and reviewed. After a thorough read of the responses, a set of codes was created to compile a frequency count of responses. The students' responses were summarized by question.

CHAPTER FIVE

Results

Overview

In this chapter, the similarities of the experimental and control samples are given followed by the results for each research question.

Prior Technology Experiences

Descriptive Statistics for Prior Technology Experiences. Ninety-three percent of the students stated on the *Prior Technology Experiences* survey that they had daily access to the computer and 99% stated that they had daily access to the Internet. The mean and standard deviations for prior experiences with technology items (scale from 1, *never* to 4, *always*) are shown in Table 5.1.

Table 5.1

Standard deviations and means for prior experiences with technologies

Technology	Control Group Mean (*SD*)	Experimental Group Mean (*SD*)
Computer/Laptop	3.47 (*.61*)	3.69 (*.60*)
Internet	3.86 (*.35*)	3.91 (*.28*)
Forums/Posts	2.64 (*.87*)	2.69 (*1.00*)
Submit Data to a Website	2.63 (*1.07*)	2.33 (*1.06*)
Upload Images/Videos	3.19 (*.82*)	2.94 (*.95*)
iPADs/Netbooks/Tablets	2.97 (*1.03*)	2.69 (*1.23*)
Download Scientific Data	1.97 (*.88*)	1.94 (*1.04*)
Telescope	1.47 (*.61*)	1.61 (*.73*)
Microscope	1.64 (*.64*)	1.64 (*.79*)

Students reported using the Internet to post pictures, upload videos and information to websites; however, use of microscopes, telescopes, or using scientific data were rarely accessed or utilized.

Similarity of Access and Use of Technologies. The results from the Fisher's Exact Test indicated that there were no differences across treatment groups' for students' access to computers or the Internet ($\chi(1) = 1.934$, $p = 0.357$; $\chi(1) = 1.014$, $p = 1.000$). Additionally, there were no differences in students' reported prior experiences with technology (Table 5.2).

Table 5.2

Prior experiences with technology

Technology	Control Group Mean Rank	Experimental Group Mean Rank	*U*	*P*
Computer/Laptop	33.19	39.81	529.00	0.115
Internet	35.50	37.50	612.00	0.465
Forums/Posts	35.74	37.26	620.50	0.745
Submit Data to a Website	39.39	33.61	544.00	0.225
Upload Images/Videos	38.99	34.01	558.50	0.285
iPADs/Netbooks/Tablets	38.65	34.35	570.50	0.360
Download Scientific Data	37.44	35.56	614.00	0.685
Telescope	34.85	38.15	588.50	0.449
Microscope	37.28	35.72	620.00	0.725

For prior experiences with technology, students in both treatment groups reported having similar experiences with various technologies prior to the remote investigation.

Prior Insect Experiences

Students reported experiences with insects are shown in Table 5.3.

Table 5.3

Percentage of students with prior experiences with insects

Experience	Yes Percentage (Frequency)	No Percentage (Frequency)
Collected Insects	26 (19)	74 (53)
Caught Insects Outdoors	67 (48)	33 (24)
Insects as Pets	00 (0)	100 (72)
Watched TV Programs about Insects	68 (49)	32 (23)
Read about Insects	64 (46)	36 (26)
Taken Video or Pictures of Insects	35 (25)	65 (47)
Would Visit a Museum that has Insects	83 (60)	17 (12)

These results showed that participants reported they collected and caught insects as well as watched television program before the *Virtual Microscopy Lab* session.

Similarity of Students' Experiences with Insects. The results from the Fisher's Exact Test indicated that there are no differences across treatment groups' with students' prior experiences with insects (Table 5.4)

Table 5.4

Reported student prior experiences with insects

Insect Experience	Control Group Frequency	Experimental Group Frequency	Value	*P*
Collected Insects	12	7	1.787	0.285
Caught Insects Outdoors	27	21	2.250	0.211
Insects as Pets	0	0	--	--
Watched TV Programs about Insects	28	21	3.130	0.129
Read about Insects	26	20	2.167	0.220
Taken Video or Pictures of Insects	16	9	3.003	0.137
Would Visit a Museum that has Insects	30	30	0.000	1.000

Post Experiences with Insects

After investigating insects with the *Virtual Microscopy Lab,* students reported their level of interest in insects (Table 5.5).

Table 5.5

Post experiences with insects after remote investigation by percent and frequency

Interest	Yes Percent (Frequency)	No Percent (Frequency)	Maybe Percent (Frequency)	No Response Percent (Frequency)
Interested in Collecting Insects After Session	25 (18)	63 (45)	10 (7)	2 (2)
Want to have Insects as Pets After Session	7 (5)	89 (64)	1 (1)	3 (2)
Want to Visit an Insect Museum After Session	76 (55)	18 (13)	3 (2)	3 (2)
Want to Participate in another *Virtual Microscopy Lab* Session	85 (61)	5 (3)	7 (5)	3 (2)

Eleven control students and seven experimental students reported they were interested in collecting insects; three control and two experimental students declared that they would be interested in having insects as pets. A majority of students indicated that they would like to visit a museum that hosted an exhibit with insects or participate in another *Virtual Microscopy Lab* session.

Influence of Ownership of Reported Post Experiences. The results from the Fisher's Exact Test indicated that after using *Virtual Microscopy Lab* there were no differences across treatment groups' for interest in insects (Table 5.6)

Table 5.6

Post experiences with insects after remote investigation with Fisher's Exact Test

Interest	Control Group Frequency	Experimental Group Frequency	Value	*p*
Interested in Collecting Insects After Session	11	7	0.693	0.580
Want to have Insects as Pets After Session	3	2	0.215	1.000
Want to Visit an Insect Museum After Session	27	28	0.077	1.000
Want to Participate in another *Virtual Microscopy Lab* Session	31	30	0.067	1.000

These results suggested that students' interests in future experiences with insects were similar after the remote investigation.

Research Question 1. Is there a relationship between *perceived ownership of data* in a remote learning session and students' motivation to engage in science?

Motivation Survey

Similarity of Perceived Motivation to do Science. The results indicated that the students in both groups reported similar levels of motivation to do science before the remote learning session. The motivation constructs mean ranks across groups, *U*, and *p* values are listed below (Table 5.7)

Table 5.7

Motivation constructs' mean ranks, U test statistic, and p-values.

Construct	Control Group Mean Rank	Experimental Group Mean Rank	*U*	*P*
Intrinsic Motivation	35.54	37.47	613.50	0.697
Career Choice	35.86	37.14	625.00	0.795
Self-Determination	35.47	37.53	611.00	0.676

Students in both groups reported being intrinsically motivated and interested in learning about science and insects. Additionally, students reported similar perceptions about science-related careers. There were no significant differences in items related to self-determination.

Influence of Remote Investigations on Students' Perception of Motivation to do Science. There was no significant change in motivation construct scores from pre to post for the control group and the experimental group (Table 5.8).

Table 5.8

Motivation constructs' Z statistic and p-value for the control and experimental group

Construct	Control Group *Z* (*p*)	Experimental Group *Z* (*p*)
Intrinsic Motivation	1.869 (*0.062*)	0.719 (*0.476*)
Career Choice	0.238 (*0.812*)	0.069 (*0.945*)
Self-Determination	0.763 (*0.446*)	1.005 (*0.315*)

Influence of Ownership on Students' Perception of Motivation to do Science. The results showed that there were no significant differences across treatment groups for constructs or individual items for motivation to do science (Table 5.9 and Table 5.10).

Table 5.9

Motivation constructs' mean ranks, U test statistic, and p-values

Construct	Control Group Mean Rank	Experimental Group Mean Rank	*U*	*p*
Intrinsic Motivation	36.17	36.83	636.00	0.892
Career Choice	34.47	38.53	575.00	0.409
Self-Determination	35.22	37.78	602.00	0.601

The results show that there were no differences across treatment groups for the motivation constructs after a remote investigation.

Table 5.10

Motivation items, mean ranks, U test statistic, and p-values

Construct	Item	Control Group Mean Rank	Experimental Group Mean Rank	*U*	*p*
Intrinsic Motivation	Learning about science is interesting.	36.06	36.94	632.00	0.849
	I am curious about discoveries in science.	37.54	35.46	610.50	0.658
	I do not enjoy learning about insects.	35.96	37.04	628.50	0.821
	The science I learn is relevant to my life.	34.24	38.76	566.50	0.334
	Learning science makes my life more meaningful.	36.11	36.89	634.00	0.868
	I enjoy learning science.	35.79	37.21	622.50	0.763
	Learning about insects is interesting.	39.00	558	0.294	0.423
Career Choice	Learning science will help me get a good job.	34.53	577	0.406	0.798
	Understanding science will benefit me in my career.	35.53	37.47	613.00	0.684
	Knowing science will give me a career advantage.	35.26	37.74	603.50	0.605
	I will use science problem-solving skills in my career.	34.38	38.63	571.50	0.377
	My career will involve science.	34.78	38.22	586.00	0.475
Self-Determination	I study hard to learn science.	34.78	38.22	586.00	0.475
	I prepare well for science tests and labs.	38.10	34.90	590.50	0.494
	I put enough effort into learning science.	37.82	35.18	600.50	0.570
	I spend a lot of time learning science.	34.00	39.00	558.00	0.290
	I use strategies well to learn science.	34.69	38.31	583.00	0.435

Students in the control and experimental groups reported similar perceptions of intrinsic motivation, career choice, and self-determination after the remote investigation.

Research Sub-question 1. Is there a relationship between *perceived ownership of data* in a remote learning session and students' sustained motivation to engage in science?

Motivation Over Time. There was no significant change in motivation scores from the pretest to the delayed posttest for the control group ($\chi^2(2) = 2.070$, $p = 0.355$). Post hoc analysis with the Wilcoxon signed-rank tests did not detect significant changes between the assessments (Table 5.11). The experimental group did not report significant changes in motivation scores from the pretest to the delayed posttest ($\chi^2(2) = .389$, $p = 0.823$). Post hoc analysis with the Wilcoxon signed-rank tests did not detect any significant changes (Table 5.11).

Table 5.11

Sustained motivation constructs' mean ranks, Z test statistic, and p-values for the control group and experimental group

Test	Control Group Z (p)	Experimental Group Z (p)
Pretest-posttest	0.459 (*0.646*)	0.715 (*0.475*)
Pretest-Delayed Posttest	0.942 (*0.346*)	0.464 (*0.643*)
Posttest-Delayed Posttest	1.540 (*0.124*)	1.453 (*0.146*)

There were no differences in the control and experimental students' perceived motivation by construct over time from pretest to delayed posttest.

Research Question 2. Is there a relationship between *perceived ownership of data* in a remote learning session and students' science identity?

Science Identity Survey

Similarity of Perceived Science Identity. The results indicated that the students in both groups had similar perceived notions of science identity before the remote learning session (Table 5.12).

Table 5.12

Science identity constructs' mean ranks, U test statistic, and p-value

Construct	Control Group Mean Rank	Experimental Group Mean Rank	*U*	*P*
Performance	33.06	39.94	524.00	0.161
Competence	35.90	37.10	626.50	0.808
Recognition	36.54	36.46	646.50	0.986

These results suggest that students' had similar perceptions of science identity before the remote investigation.

Influence of Remote Investigations on Students' Perception of Science Identity. There were significant changes in science identity construct scores from pre to post for the control group and the experimental group (Table 5.13).

Table 5.13

Science identity constructs, Z test statistic, and p-values for the control and experimental group

Constructs	Control Group *Z* (*p*)	Experimental Group *Z* (*p*)
Performance	5.17 (*0.000**)	5.17 (*0.000**)
Competence	4.30 (*0.000**)	4.12 (*0.000**)
Recognition	2.02 (*0.043**)	2.98 (*0.003**)

Note. *p*-value less than .05.

The control and experimental groups had significant changes in perceptions of performance, competence, and recognition after a remote investigation.

Influence of Ownership on Students' Perception Science Identity. The results show science identity was not significantly different for the control and experimental groups.

Table 5.14

Science identity constructs' mean rank, U test statistic, and p-value

Construct	Control Group Mean Rank	Experimental Group Mean Rank	*U*	*P*
Performance	35.04	37.96	595.50	0.554
Competence	36.94	36.06	632.00	0.857
Recognition	39.64	33.36	535.00	0.202

Although the science identity scores changed significantly from pre to post remote investigation, there were no differences in students' perceived science identity across treatment groups.

Research Question 3. What are students' *perceived presence* (how *real* is it) during a remote access investigation?

Presence Survey

The presence constructs (control, sensory, distraction, and realism) were compared. As seen in Table 5.15, there were no significant differences in the scores of the students in the control and treatment groups.

Table 5.15

Presence construct's mean ranks, U test statistics, and p-values.

Construct	Control Group Mean Rank	Experimental Group Mean Rank	*U*	*P*
Control	36.89	36.11	684.00	0.874
Sensory	35.26	37.74	603.50	0.613
Distraction	37.92	35.08	597.00	0.563
Realism	26.83	25.75	276.00	0.810

Presence Survey Items. When asked if the students felt in control of the computer program (item 2), there were significant differences in the responses of students who investigated their own insect and those that investigated a class insect. The students in the control group perceived that they were in control of the computer program (Table 5.16).

Table 5.16

Statements item, mean ranks, U test statistic, and p-value for perceived control.

Item Number	Item	Control Group Mean Rank	Exp Group Mean Rank	*U*	*P*
1	I was in control when participating in the *Virtual Microscopy Lab* session.	38.22	35.78	622.00	0.761
2	The *Virtual Microscopy Lab* computer program would respond to my directions.	41.25	31.75	477.00	0.046*
3	I enjoyed controlling the *Virtual Microscopy Lab* session.	34.36	38.64	571.00	0.365
4	I was able to move around in the *Virtual Microscopy Lab* session with ease.	33.07	39.93	524.00	0.153
5	My interactions with the *Virtual Microscopy Lab* program were natural and easy.	32.26	40.74	495.50	0.078
6	I can easily manipulate the *Virtual Microscopy Lab* program in any way I want.	37.04	35.96	628.00	0.817
7	I was able to interact easily with the *Virtual Microscopy Lab* program.	35.28	37.72	604.00	0.609
8	I was able to chat easily with the *Virtual Microscopy Lab* scientists through the chat window.	42.00	31.00	450.00	0.017*

Note. *p* value less than .05.

There were also significant differences by treatment and control group. For the item that asked if students could easily chat with scientists through the chat box, the control groups were more likely to report they are able to chat easily with scientists. The control students who investigated the class insects reported the *Virtual Microscopy Lab* program would respond to their directions and were able to chat with the scientists easily than the experimental group.

Teacher and Student Interviews: Control and Interaction with Scientists.

All students reported that they were able to manipulate the controls easily, and they felt they made a connection with the scientists because they were able to ask questions and receive quick responses in the chat box screen. The students felt that they were able to freely ask questions with the scientists in which they thought the scientists were very personable and likeable.

All the teachers stated that it is extremely important for all the students to be able to communicate with scientists during a remote investigation. Teacher 3 stated that it "…should be a priority in all science classes" to use technology that enables students to communicate with scientists. Teacher 1 believed that scientists can give students assistance during an experiment. Furthermore, she noted that if students have questions that teachers may not be able to answer, "…the scientists can help answer those questions for us." Teacher 2 indicated the importance of having students communicate with scientists is to enable students "…to discuss and view things from different perspectives…from other classmates, scientists, and teachers."

Table 5.17

Statements item, mean ranks, U test statistic, and p-value for perceived sensory factors.

Item Number	Item	Control Group Mean Rank	Exp Group Mean Rank	*U*	*p*
1	My sense of sight was highly engaged when participating in the *Virtual Microscopy Lab* session.	33.99	39.01	557.50	0.288
2	My sense of hearing was highly engaged when participating in the *Virtual Microscopy Lab* session.	38.67	34.33	570.00	0.362
3	My sense of touch was highly engaged when participating in the *Virtual Microscopy Lab* session.	33.75	39.25	549.00	0.240
4	All my senses were highly engaged when participating in the *Virtual Microscopy Lab* session.	36.39	36.61	644.00	0.962

There were no reported differences between the control group and the experimental group for sensory factors during a remote investigation.

Table 5.18

Statements item, mean ranks, U test statistic, and p-value for perceived distractions.

Item Number	Item	Control Group Mean Rank	Exp Group Mean Rank	*U*	*P*
1	When participating in the *Virtual Microscopy Lab* session, I was aware of other events occurring around me.	35.46	37.54	610.50	0.662
2	When participating in the *Virtual Microscopy Lab* session, I was aware of the computer program I was using.	50.61	22.39	140.00	0.000*
3	When participating in the *Virtual Microscopy Lab* session, I was aware of other sounds around me.	52.47	20.53	73.00	0.000*
4	When participating in the *Virtual Microscopy Lab* session, I was aware of the *Virtual Microscopy Lab* scientists.	36.31	36.7	641.00	0.936
5	When participating in the *Virtual Microscopy Lab* session, I could tell where other sounds were coming from.	41.63	31.38	463.50	0.033*
6	I was easily distracted when participating in the *Virtual Microscopy Lab* program.	36.31	36.69	641.00	0.935
7	The *Virtual Microscopy Lab* scientists distracted me when I was using the *Virtual Microscopy Lab* program.	35.43	37.57	609.50	0.648
8	The *Virtual Microscopy Lab* program distracted me from learning.	34.33	38.67	570.00	0.363
9	I can concentrate easily while participating in the *Virtual Microscopy Lab* session.	23.68	49.32	186.50	0.000*
10	The *Virtual Microscopy Lab* scientists did not confuse me during the learning session.	23.24	49.76	170.50	0.000*

Note. *p* value less than .05.

Students were asked to rate perceived distractions and the students in the control group were significantly more likely to report being aware of the computer program, sounds, and location of sounds than students in the experimental group. On the other hand, the treatment group students were more likely to report being able to easily concentrate and not being confused during interactions with the scientists.

Table 5.19

Item mean ranks, U test statistic, and p-value for perceived realism.

Item Number	Item	Control Group Mean Rank	Exp Group Mean Rank	*U*	*P*
1	I could transition from the real world to using the *Virtual Microscopy Lab* program with ease.	26.61	26.25	284.00	0.935
2	I lost track of time when participating in the *Virtual Microscopy Lab* session.	27.13	25.09	265.50	0.636
3	I quickly adjusted to using the *Virtual Microscopy Lab* program.	26.94	25.50	272.00	0.733

Students in the control and in the experimental group reported similar levels of perceived realism factors.

Teacher and Student Interviews: Perceptions of Realness. There were differences in perceptions of how *real* a remote investigation is for students and teachers. The teachers regarded the *realness* of the *Virtual Microscopy Lab* session as *somewhat real*. Teacher 1 stated that it was real in that "…students could use a scanning electron microscope in our computer lab;" however, "…students are not using the microscope in a facility." Teacher 2 had similar ideas in which she proclaimed that it was real for students because they were able to operate and change the functions on the computer screen, "…but there is a disconnect between the students and the microscope/scientists because it is through the internet." The teachers strongly felt that while the remote investigation was engaging and exciting while enabling the students to use a scanning electron microscope and communicate with scientists, the *realness* of the experience was reduced because the students and the technology/scientists were not located in the same location.

All students stated that the experiences was *very real* with the exception of one experimental student that stated it was not real because he was not actually using a scanning electron microscope in a laboratory, which is a similar notion to teachers' perceptions. Student (C,3) remarked that it felt that it was so real that "It felt like the bug was sitting on my computer. Like…when I first came in [the computer lab], I got scared!" Another student (E, 4) stated that interacting with the scientists made it feel real, "…it didn't seem like a computer program answering the questions…the scientists were actually interacting with us."

In addition, most students reported loosing track of time during the sessions. One student (C,1) stated that she lost track of time, "I was zoned into the session, then it would be time to go. And I was like 'man…is it time to go now?'" Another student (C,3) declared that he "…didn't want to leave," while student (E,1) lost track because "…I was so interested in what was going on."

Research Question 4. Does *Virtual Microscopy Lab* facilitate learning?

Learning Outcomes Assessment

Descriptive Statistics. The means of the pretest and posttest scores are shown in Table 5.20.

Table 5.20

The mean and standard deviation of the pretest and posttest scores of the Learning Outcomes Assessment

Assessment Scores	N	Mean	Std. Deviation
Pretest Scores	72	38.25	18.10
Posttest Scores	72	64.88	20.09

Establishing Normality. The items on the *Learning Outcomes Assessment* were evaluated to determine the normality of the pretest and posttest score distributions.

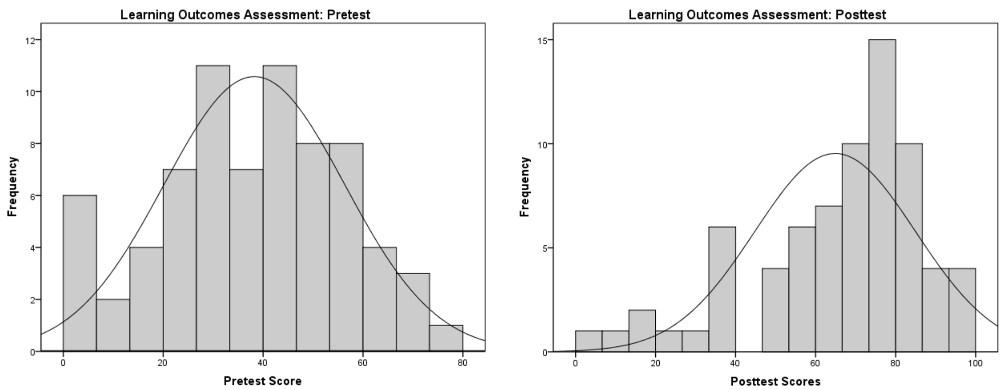


Figure 5.1. Histograms of the pretest and posttest scores of the *Learning Outcome Assessment*.

The pretest scores followed a normal distribution. The Shapiro-Wilk test indicated normality (p = .107). The posttest scores were not normally distributed (Shapiro-Wilk , p < .000).

Similarity of Initial Knowledge Level. Students' pretest scores showed that the students in both groups had similar levels of knowledge of insects and microscopy before the remote learning session, t (70) = 1.443, p = .153.

Ownership of Data Learning Influence. Across treatment groups, the results suggest that the experimental group posttest scores were not different from the control group (U = 556, p = .296).

Remote Investigation Learning Influence. There was a significant improvement in scores from pre to post for the control group [$Z = 4.248$, $p < .000$] and the experimental group [$Z = 4.788$, $p < .000$].

Research Question 5. What are the constraints and affordances of *Virtual Microscopy Lab*?

Teacher Interviews

All three teachers believed remote technologies utilized in science classrooms are valuable tools to enable students to "…explore scientific concepts in a novel way." (Teacher 1). Teacher 1 also stressed the importance of student access to microscopes and scientists. She stated that most students in her classrooms have never talked to a scientist before or used research-grade microscopes during the students' school experiences. She stated that the remote investigation may inspire her students to continue to pursue their interests in science. Teacher 2 noted that the benefits of remote investigations are more affective in nature, stating that remote investigations are "exciting and engaging" for students. Teacher 3 stated that remote technologies are "great educational tools" which "helps out financially" because it limits the costs of not having to fund a fieldtrip or buy expensive equipment to do science in the classroom.

Discussing the constraints of remote laboratories, all three teachers made similar remarks that the main constraint of a remote investigation is that the experiences are not very interactive or real (as compared to students stating that they felt the experiences was *very real*). Teacher 1 believed that it was not realistic because the students "…are not in the lab."

Teacher 2 specifically stated that it would be "…difficult to have one-on-on interactions." However, she understood that having one-on-one interactions with the technology and the scientists would be time consuming and resource-limited.

After discussing the constraints and benefits of remote laboratories, all three teachers were asked to discuss *Virtual Microscopy Lab* in relation to constraints and benefits of using the program in their classroom. Teachers 2 and 3 stated that *Virtual Microscopy Lab* ignited students' interest and curiosity in learning about insects. Teacher 2 specifically declared that the program "…stimulated students' curiosity about insects," which she indicates that it is sometimes "…hard to engage" students in science. Teacher 3 mentioned that the only tools needed for the program was a computer and an internet connection. Additionally, Teacher 3 stated that "[*Virtual Microscopy Lab*] is easy to use and does not cost money…which is a great advantage for our school." As observed in question one, Teacher 1 stated that the benefits of this program enabled students to access a scanning electron microscope because "…more than likely students will never have that opportunity if this program did not exist."

However, all three teachers stated that they wished the program could be more one-on-one for the students. The teachers recognized that time and resources were limitations to their proposed ideas. It is to be noted that the teachers did not state that there were any constraints of the *Virtual Microscopy Lab* program; rather the constraints were how the classroom was structured.

All three teachers were asked to share any additional thoughts that they would like to share about the remote investigation sessions. Teachers 1 and 3 mentioned that this was a great experience for the students and that they will strongly consider using the technology in their classrooms again. Interestingly, Teacher 2 stated that the project stimulated the students' curiosity about insects so much that they students continued to ask questions about insects and the scanning electron microscope in class. Because of this interest, Teacher 2 changed the students' end-of-semester project to research of different insects. Students were able to report out the characteristics and ecological impact of their chosen insect order.

Interest in Insects

Descriptive Statistics. The means and standard deviations of *Interest in Insects* of the pretest, posttest, and delayed posttest scores are shown in Table 5.21.

Table 5.21

Interest in insects means and standard deviations

Surveys	Control Group Mean (*SD*)	Experimental Group Mean (*SD*)
Pretest	2.50 (*1.06*)	2.75 (*1.25*)
Posttest	3.27 (*1.13*)	3.06 (*1.10*)
Delayed Posttest	2.94 (0.*93*)	3.05 (*1.09*)

Similarity of Interest in Insects. The results indicated that the students in both groups had similar interest in insects before the remote learning session ($U = 566.5$, $p = .339$).

Influence of Ownership on Students' Interest in Insects. The results showed that the students in the experimental group had similar interest in insects to the students in the control group ($U = 578.5$, $p = .540$).

Interest in Insects Over Time. There was a significant change in students' reported interest in insect scores over time for the control group ($\chi^2(2) = 10.517$, $p = 0.005$). Post hoc analyses with the Wilcoxon signed-rank tests results showed that the control group had a significant increase in interest in insects from pretest to posttest and sustained motivation from pretest to delayed posttest (Table 5.24). The experimental group did not report significant changes in interest in insects from the pretest to the delayed posttest ($\chi^2(2) = 3.571$, $p = 0.168$). Post hoc analysis with the Wilcoxon signed-rank tests resulted with no differences (Table 5.25).

Table 5.22

Sustained interest in insects, Z test statistic, and p-values for the control and experimental group

Constructs	Control Group *Z* (*p*)	Experimental Group *Z* (*p*)
Pretest to Posttest	2.71 (0.*007**)	1.37 (*0.170*)
Pretest to Delayed Posttest	2.02 (0.*043**)	1.29 (*0.196*)
Posttest to Delayed Posttest	1.24 (0.*213*)	0.12 (*0.904*)

Note. p value less than .05.

The control group had significant changes in interest in insects from pretest to posttest. Additionally, the changes remained significant from pretest to delayed posttest. There was no difference in the experimental groups' interest in insects between the pretest, posttest, and delayed posttest time periods.

Interest in Insects: Student Interviews. Overall, the students thought the insects were extremely interesting to view. A few students in the control and experimental interview stated that while the insects looked interesting on the screen, they had a fear of insects. A female student in the control group stated "I'm glad they were on the computer screen and not on my desk. I don't think I would have liked it if the bugs were not on the computer."

However, there were students in both groups that wanted to continue to learn about insects after the remote investigation. Student (E,3) wanted to continue to learn more about insects because "…I think bugs are interesting. Like…I liked the wasps and the yellow jackets. I think those are interesting. And spiders! But they aren't insects." Student (C,5) stated that he would also like to continue to learn about insects because "…I need to get over my fear of insects…which is my main fear. If I learn more about them, I might come to like them."

Remote Learning Environment Model

The results of this study were examined in light of the proposed *Remote Learning Environment Model*. This model (based on primary research) described possible relationships for students' motivation to do science and their perception of science identity during a remote investigation that included scientist and technology interactions mediated by virtual presence (see Figure 5.2). To explore the relationships between the constructs and the factors within each construct in the *Remote Learning Environment Model*, correlations using Spearman rank-order coefficient were calculated to determine the association between variables among the treatment groups. An exploratory factor analysis was conducted on the constructs and their factors in the *Remote Learning Environment Model* to identify relationships between the variables. Once new factors were identified as contributing to students' remote learning experiences, the newly constructed variables were compared utilizing the Mann-Whitney U test.

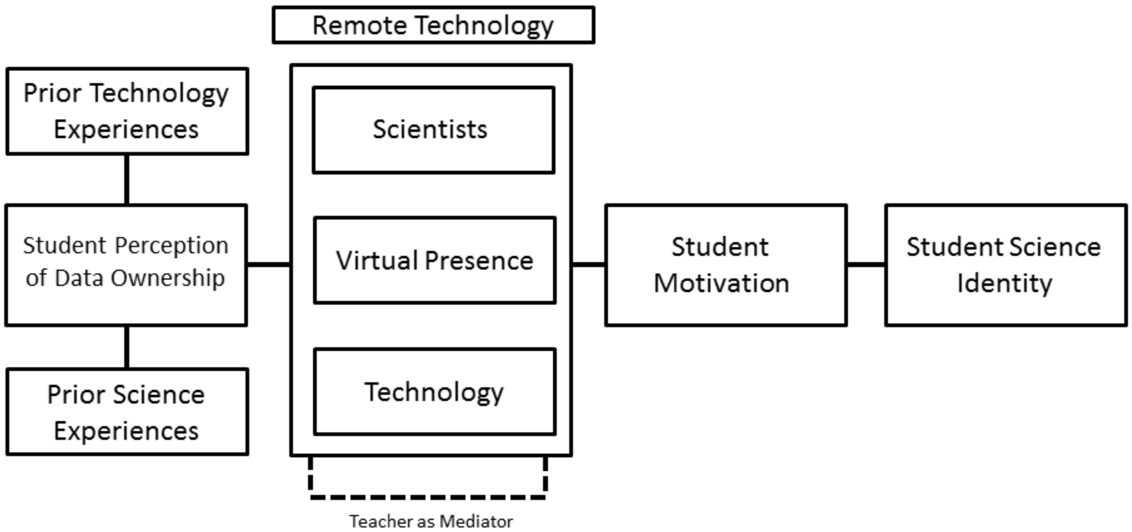


Figure 5.2. A hypothesized model of presence, self-determination, and science identity in the remote learning environment.

Construct correlations: Remote Learning Environment Model. The control group and experimental had significant correlations between constructs which are listed in Table 5.26 and Figure 5.3 below.

Table 5.23

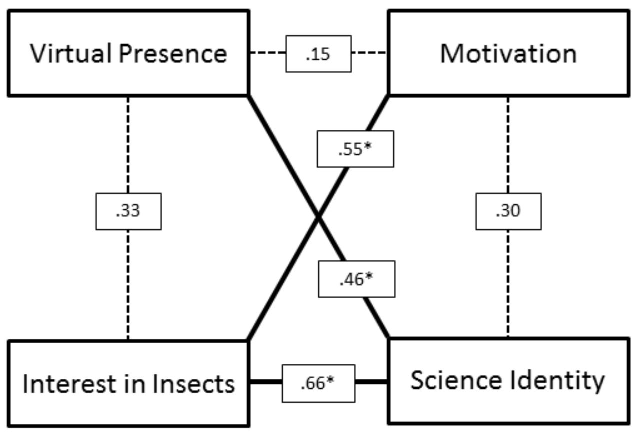
Control group correlations between constructs identified in the remote learning model

Constructs	*n*	Spearman's Correlation Coefficient	*P*
Presence and Science Identity	34	0.46	0.004
Motivation and Interest in Insects	33	0.55	0.001
Interest in Insects and Science Identity	33	0.66	0.000*

Note. *p* value less than .05.

In the *Remote Learning Model* there were positive, significant correlations between presence and science identity, motivation and interest in insects, and interest in insects and science identity for the control group.

The relationships between all the variables in the current study are shown for the control group in the *Remote Learning Environment* are shown in Figure 5.3 below.



*Significant Spearman Correlation Coefficient

Figure 5.3. Construct correlations for the remote learning model control group.

Table 5.24

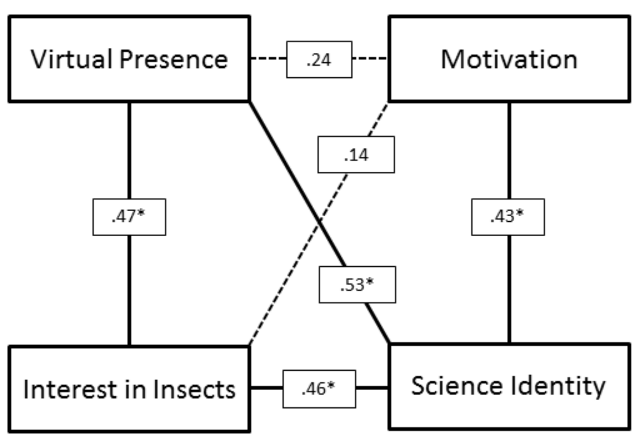
Correlations between constructs identified in the remote learning model for the experimental group

Constructs	*n*	Spearman's Correlation Coefficient	*P*
Presence and Science Identity	34	0.53	0.001*
Presence and Interest in Insects	34	0.47	0.004*
Motivation and Science Identity	34	0.43	0.008*
Interest in Insects and Science Identity	34	0.46	0.005*

Note. *p* value less than .05.

There were significant correlations between presence and science identity, presence and interest in insects, motivation and science identity, and interest in insects and science identity for the experimental group.

The relationships between all the constructs for the experimental group in the Remote Learning Environment are located in Figure 5.4 below.



*Significant Spearman Correlation Coefficient

Figure 5.4. Construct correlations for the remote learning model experimental group.

These results suggest that there are positive relationships between the constructs identified in the *Remote Learning Model*. There were differences in the relationships between the constructs across treatment groups. The control group's perception of science identity and interest in insects appears to be the stronger association between constructs. However, the experimental group's perception of science identity and virtual presence displays a stronger relationship during the remote investigation than for the control group.

Exploring the Relationships between Factors within each Construct. The factors within each construct are located in Figure 5.5 below. An additional variable, *Interest in Insects,* was added based on the responses on the interest item given during the pretest, posttest, and delayed posttest and the assumption that interest in insects may alter students' perceptions during the course of the study. There were significant correlations between factors within each construct for the control and experimental groups.

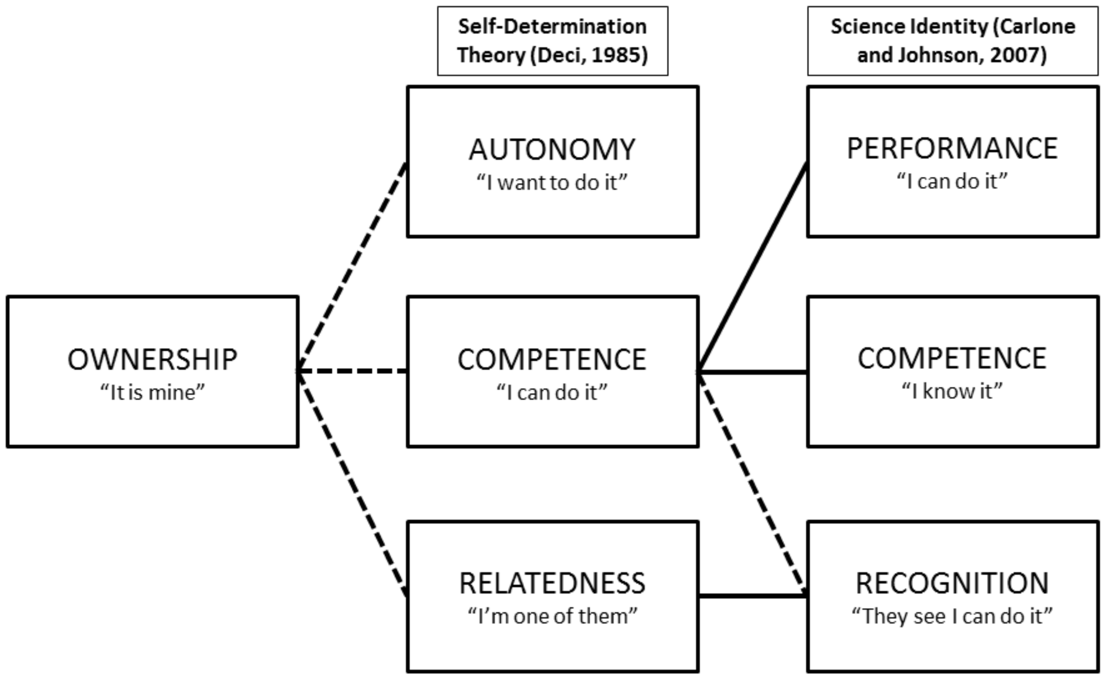


Figure 5.5. The hypothesized relationship of self-determination and science identity factors that relate to student perception of ownership of data. All calculated correlations for the control group and experimental group are listed below in Table 5.25 and Table 5.2.

Table 5.25

Spearman's correlation p-values between factors within each construct for the control group (significance level = .05)

	Control	Sensory	Distractions	Realism	Intrinsic Motivation	Career Motivation	Competence (Motivation)	Relatedness	Autonomy	Performance	Recognition	Competence (Identity)	Insect Interest
Control		0.012*	0.003*	0.000*	0.110	0.412	0.000*	0.000*	0.157	0.041*	0.008*	0.081	0.201
Sensory			0.051	0.000*	0.213	0.781	0.504	0.853	0.574	0.188	0.021*	0.010*	0.051
Distraction				0.025*	0.382	0.560	0.882	0.443	0.255	0.440	0.683	0.974	0.501
Realism					0.039*	0.512	0.264	0.010*	0.039*	0.000*	0.650	0.000*	0.009*
Intrinsic Motivation						0.001*	0.885	0.068	0.015*	0.000*	0.115	0.000*	0.000*
Career Motivation							0.218	0.772	0.109	0.003*	0.246	0.010*	0.480
Competence (Motivation)								0.008*	0.429	0.851	0.782	0.859	0.810
Relatedness									0.047*	0.039*	0.453	0.119	0.223
Autonomy										0.010*	0.034*	0.049*	0.006*
Performance											0.094	0.000*	0.001*
Recognition												0.074	0.080
Competence (Identity)													0.000*
Insect Interest													

Table 5.26

Spearman's correlation p-values between factors within each construct for the experimental group (significance level = .05)

	Control	Sensory	Distractions	Realism	Intrinsic Motivation	Career Motivation	Competence (Motivation)	Relatedness	Autonomy	Performance	Recognition	Competence (Identity)	Insect Interest
Control		0.000*	0.000*	0.010*	0.001*	0.014*	0.642	0.000*	0.054	0.012*	0.046*	0.002*	0.005*
Sensory			0.002*	0.049*	0.009*	0.019*	0.354	0.001*	0.002*	0.169	0.700	0.006*	0.002*
Distraction				0.821	0.050*	0.314	0.598	0.007*	0.207	0.166	0.991	0.180	0.470
Realism					0.583	0.397	0.419	0.251	0.817	0.309	0.212	0.064	.0162
Intrinsic Motivation						0.000*	0.352	0.002*	0.005*	0.050*	0.065	0.021*	0.007*
Career Motivation							0.476	0.045*	0.000*	0.006*	0.755	0.008*	0.246
Competence (Motivation)								0.031*	0.463	0.475	0.850	0.924	0.879
Relatedness									0.012*	0.107	00.374	0.061	0.009*
Autonomy										0.019*	0.525	0.082	0.022*
Performance											0.599	0.000*	0.098
Recognition												0.784	0.062
Competence (Identity)													0.020*
Insect Interest													

Factor Analysis of the Constructs for the Remote Learning Environment. An exploratory factor analysis revealed the core of variables that contribute to students' perceptions of motivation to do science, science identity, and virtual presence during remote investigations. Assumption checks for the thirteen variables were established. Inter-correlations between factors generally exceeded .30 with many correlations over .50 for each factor set. Correlations exceeding .30 indicate that there is a justification of factorability (Tabachnick & Fidell, 2001). Bartlett's Test of Sphericity was calculated ($p < .000$) indicating that there was evidence for linear combinations in the factor data set (Beavers, Lounsbury, Richards, Huck, Skolits, & Esquivel, 2013). Additionally, for assumption measures, the Kaiser-Myer-Olkin (KMO) Test of Sampling to measure the shared variance in the factors was calculated with a value of 0.73. KMO values of 0.60 or higher indicate an appropriate degree of variance between factors for an exploratory factor analysis (Dziuban & Shirkey, 1974; Kaiser & Rice, 1974). These analyses supported the selection of a factor analysis as an initial exploratory approach of examining the variables in the remote learning environment.

Thirteen variables were analyzed with factor analysis using the principal component analysis of extraction utilizing the Varimax rotating method. The exploratory factor analysis yielded four factors (Eigenvalues over 1.000) accounting for 71.96% of the variance.

Based on the factor loadings, Factor 1 consists of students' perceptions of science identity of *performance* "I can do it" and *competence* "I know it" along with *intrinsic motivation*. Factor 2 consists of virtual presence factors that included *sensory*, *control*, and *distraction* in a virtual environment in conjunction with motivation factor of *relatedness* "I am one of them." Factor 3 and Factor 4 shared a common component, *realism* "how real is the remote environment to me" that loaded with *recognition* "they see I can do it" and motivation *competence* "I can do it". Because *realism* is heavily factored into two distinct factors, a revised exploratory factor analysis was conducted in which three factors are identified.

The revised exploratory factor analysis factored the thirteen variables by using the principal component analysis of extraction utilizing the Varimax rotating method into three factors. The exploratory factor analysis yielded three factors (Eigenvalues over 1.000) accounting for 63.28% of the variance for all thirteen variables (Table 5.27).

Table 5.27

Exploratory factor analysis for three factors

	Initial Eigenvalues			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.337	41.055	41.055	3.516	27.042	27.042
2	1.644	12.647	53.702	2.803	21.558	48.601
3	1.246	9.582	63.284	1.909	14.683	63.284
4	1.128	8.675	71.959			
5	.790	6.078	78.037			
6	.742	5.709	83.746			
7	.542	4.166	87.912			
8	.458	3.525	91.437			
9	.406	3.120	94.557			
10	.277	2.132	96.689			
11	.209	1.610	98.300			
12	.124	.957	99.257			
13	.097	.743	100.000			

Note: Extraction Method: Principal Component Analysis.

Based on the factor loadings in Table 5.28 below, Factor 1 consists of students' perceptions of science identity of *performance* "I can do it" and *competence* "I know it" along with *intrinsic motivation*. Factor 2 consists of virtual presence factors that included *sensory*, *control*, and *distractions* in a virtual environment in conjunction with motivation vein of *relatedness* "I am one of them." Factor 3 consists of *realism* "how real is the remote environment to me" and science identity factor of *recognition* "they see I can do it."

Table 5.28

Three identified factors: Science learning drive, environmental presence, and inner realism presence

	Component		
	Science Learning Drive	Environmental Presence	Inner Realism Presence
Presence_Control	.230	.704	.501
Presence_Sensory	.312	.685	.237
Presence_Distractions	.257	.752	-.281
Presence_Realism	.115	.322	.682
Motivation_Intrinsic	.746	.343	.217
Motivation_Career	.721	-.036	.096
Motivation_Competence	-.188	.452	.160
Motivation_Relatedness	.272	.768	.230
Motivation_Autonomy	.655	.420	.056
SciID_Performance	.868	.110	.083
SciID_Recognition	.074	-.015	.733
SciID_Competence	.844	.127	.166
InterestinInsects	.448	.220	.590

Note: Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

The first factor explained 27.04% of the variance and was labeled *Science Learning Drive* due to the high loading of science identity variables *performance* and *competence* and *intrinsic motivation*. This suggests that students reporting a higher *Science Learning Drive* in a remote learning environment may perceive themselves as having higher self-efficacy in areas that relate to utilizing remote technology, communicating with scientists, and learning science. Higher self-esteem may stimulate students' innate desire to learn science in a remote investigation.

The second factor, which accounts for 21.56% of the total variance, was labeled *Environmental Presence* because of loading of presence variables *control*, *sensory*, and *distraction* along with the motivation variable, *relatedness*. *Environmental Presence* may describe how students' perceive themselves in conjunction with their physical interactions with the technology and scientists during a remote investigation. The presence variables in this factor are physically based within the students' proximate environment, which includes the student, computer, and remote technology program. The students are aware of their immediate surroundings that may relate to their perception of control over the technology and learning. Distractions in the environment may influence how students interact with the remote investigation along with how the student interprets sensory information (noises, use of a mouse/keyboard, pictures on the computer).

Factor three, labeled *Inner Realism Presence*, accounted for 14.6% of the total variance. The *Inner Realism Presence* is contributed to the high loading of a presence variable, *realism*, and science identity variable, *recognition*. If students perceive that the remote learning environment is realistic (*I'm actually using a real scanning electron microscope! I'm actually talking to real scientists!*), a successful remote investigation may influence their innate desire to be recognized as a science-oriented individual because the students were in control in a learning environment that was perceived as being *real*. Based on the results of the factor analysis, an updated *Remote Learning Environment Model* is located in Figure 5.6 below.

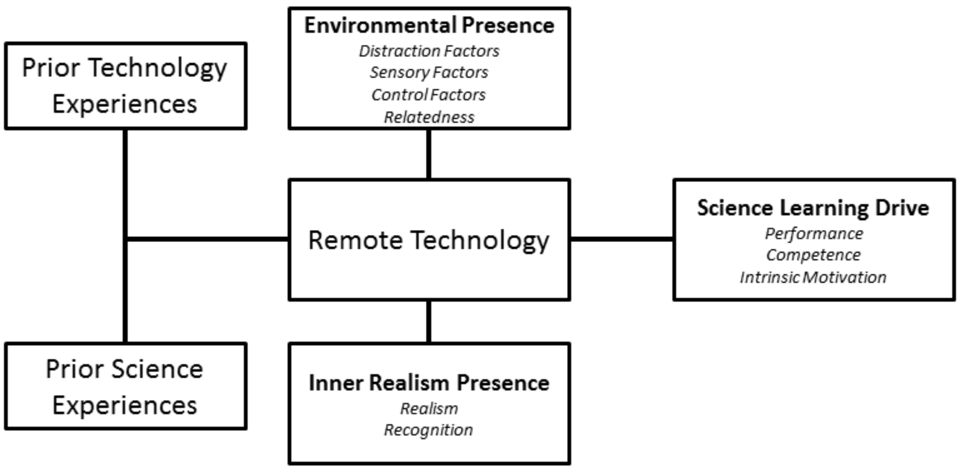


Figure 5.6. The revised remote learning environment model that incorporates *science learning drive*, *environmental presence*, and *inner realism presence* in the hypothesized relationships to the student and the remote learning environment.

Influence of Ownership on Science Learning Drive, Environmental Presence, and Inner Realism Presence. The results suggested that the experimental group posttest scores of each new construct were not different from the control group (Table 5.29).

Table 5.29

Revised factors' mean ranks, U test statistic, and p-value

Construct	Control Group Mean Rank	Experimental Group Mean Rank	*U*	*p*
Science Learning Drive	36.90	36.10	633.50	0.870
Environmental Presence	36.44	36.56	646.00	0.982
Inner Realism Presence	39.51	33.49	539.50	0.221

The results show that there were no significant differences in students' *science learning drive*, *environmental presence*, and *inner realism presence* across treatment groups after a remote investigation.

CHAPTER SIX

Discussion

Because of the rapid advancements in technologies, understanding the implications of utilizing remote access technologies in education is significant. This study provided information on the interaction of influences of students' perceptions of motivation, science identity, ownership of data, and virtual presence in a remote learning environment. The results of the study showed the following:

1. There were no differences between the experimental and control group for reported perceptions of motivation to do science, science identity, virtual presence, and learning outcomes.

2. Remote investigations influenced students' perceptions of science identity, learning outcomes, and the control groups' interest in insects.

3. The experimental group reported as being significantly less distracted than the control group; the control group was more likely to report being in control of the scanning electron microscope than the experimental group during a remote investigation.

4. Overall, the participants reported the remote investigation were *very real*; however, the teachers were less likely to describe the investigation as being *real*.

5. According to the exploratory factor analysis, three constructs, *Science Learning Drive*, *Environmental Presence*, and *Inner Realism Presence*, influenced how students engaged with the technology and scientists in a remote investigation.

This chapter discusses the implications and explanations of the observed findings of remote investigations.

Students' Perceptions of Ownership of Data in a Remote Investigation

According to the results of this study, the experience of selecting an insect to investigate did not influence students' perceptions of motivation, science identity, virtual presence, and learning outcomes. The selections of their own insect to investigate offered a unique learning experience for the students to be able to contribute, view, and analyze their own insect. The study began with the premise that *ownership of data* ("It is mine") would influence students' motivation to do science and shape students' perception of science identity. The rationale was that if students are empowered with their own data collection in a science investigation, *ownership of data* could influence students' perceptions of autonomy ("I want to do it"), competence ("I can do it"), and relatedness ("I'm one of them"). However, results showed that motivation constructs (autonomy, competence, and relatedness), were not significantly different between the two groups. For this study, *ownership of data* did not significantly motivate students in a remote investigation.

The three teachers that participated in the remote investigation noted that from their perspectives as teachers, it was vital for the students to choose their own insect because it stimulates the students' excitement and makes the students' feel like they are part of a real research group. Teacher 1 stated that it was important for students to select their own insects because the students could "…develop their own experiments." Teacher 2 reasoned that it was important for students to choose their own insect to view with the scanning electron microscope so that students could compare their insect choice to other classmates' insect choices. Teacher 3 mentioned that it made students "…feel that they are part of a research project" because it gave students the autonomy to research their own interests in insects. Based on the teachers' responses, it appeared that the teachers believed student *ownership of data* is beneficial during remote investigations. However, selecting the object to investigate did not influence motivation, science identity, virtual presence, and learning outcomes more than those students who investigated the class insect.

While there were no significant differences in students' perceptions of *ownership of data* and the constructs identified in the *Remote Learning Environment Model,* there were interesting differences in the student interview responses between the control and experimental groups, which shows how *ownership* of the insect was reasoned by the students. These differences in responses are listed below:

1. Experimental students were able to identify their insect by their personal label of the insect or an anatomical feature on the selected insect.
2. Experimental students often named their selected insect.
3. Control and experimental students stated that a more capable individual, like a scientist, should take care of the insect after the investigation.

4. Experimental students often stated that it was important to be able to view their own insect and other students' insects to compare and contrast anatomical parts.

The five students in the experimental group were asked how they knew that the insect they chose was the insect displayed on the screen. Three experimental students were able to tell it was their insect based on their labeling of each picture. Two of the experimental students were able to tell which insect belong to their group because of the insect features displayed on the screen. One student mentioned that when their group was in the process of putting their insect into a vial to be sent to the scientists, they realized that they mishandled their insect because the insect's head was separated from the body. Another student stated that they specifically chose their insect because of the weird formation of the wings. This wing deformity enabled the student to identity their insect from the other insects displayed on the screen. Additionally, four of the five students in the experimental group stated that they named their insect during the insect selection process.

As a whole, most of the students believed that a more capable person, such as a teacher or scientist should take care of the insects after a remote investigation because the more capable person could properly take care of the insects or use the insects in remote investigations for other schools and students. Some students felt that it was important for them to contribute for others that may not have the same opportunity.

Furthermore, most students thought it was interesting to view their insect and other students' insects to compare the similarities and differences of their choices. Students stated that it would be more interesting to view an insect they collect rather than be chosen by a teacher; however, two students (one from the control group and one from the experimental group) stated that they would prefer to view insects chosen by the teacher because they felt the teacher would be more qualified to pick better specimens to view with a scanning electron microscope.

Students' perceptions of *ownership of data* may not have influenced motivation, science identity, virtual presence or learning outcomes because of the following reasons:

1. The student collection protocol of insects may not have been significant in establishing *ownership of data*.

2. Students' perceptions of *ownership of data* may change when they interact with scientists handling their selected insect in a remote investigation.

The students in the experimental group may not have identified with *their insect* for the remote investigation. O'Neill and Barton (2010) suggested that *ownership* can be influenced by several factors, including purposeful utilization of appropriate materials, resources, time, and peer interactions. Students may not have had enough time during the insect collection phase to develop a personal connection that *this is my insect*. In addition, students in the experimental group were placed into groups of three for the investigation. There may have been a group dynamic that influenced their perception of *this is my insect*, *this is our insect*, or *this is no longer my insect*. It is also possible that students may have felt removed from the *ownership* of the insect once it was sent to the scientists for imaging.

Because there may be other factors that influence students' perceptions of *data ownership*, future studies are needed to document which factors contribute to students' understanding and awareness of *ownership* in science. Furthermore, as virtual and remote technology grows in popularity, more studies are needed to understand students' identification with the objects, tools, and processes that are involved. Until these factors are identified, the implications *ownership of data* in a science classroom may not be fully realized and under-utilized as a necessary factor for positively influencing students while investigating science.

Remote Investigations Influencing Students' Perceptions of Science Identity and Learning Outcomes

The results of the *Virtual Microscopy Lab* indicated a positive influence on students' perceptions of science identity and learning outcomes. Students across treatment groups reported significantly higher scores of constructs related to science identity, *performance* ("I can do it"), *competence* ("I know it"), and *recognition* ("They see I can do it"). These results were further supported by students' responses in the interviews. When asked "*Do you think you could be like one of the Virtual Microscopy Lab scientists?*" a female student responded: "I actually think I could because I can control the equipment…if I can just learn what they already know, then I can answer other people's questions [about insects]." (Student C,1). Representing *performance*, students were asked to "*Describe your experiences with Virtual*

Microscopy Lab," in which students were able to describe in detail of what they did with remote the program, what they were able to accomplish, and how they were able to interact with the scientists. The *competence* construct was well represented with the learning outcomes assessment measure. The scores on the learning outcomes assessment significantly improved from pretest to posttest suggesting that the remote program, *Virtual Microscopy Lab*, was effective in teaching students about insects. Previous research has shown that remote learning environments can increase academic achievement (Walsh, Sun, & Riconscente, 2011).

The results demonstrated that remote can influence students' *performance*, *competence*, and *recognition*. Remote learning environments enable students to be *active participants and learners* in which they are able to absorb the intricacies of remote learning environments that promote social interactions between students and scientists (Aschbacher, Li, & Roth, 2010). The results of the science identity survey suggested that students' were actively engaged as learners creating a community where learning about insects occurred. Interactions with the scientists appeared to be an important facet of the student experience. One student stated "…[the scientists] were very helpful when we were asking questions. They were eager to answer our questions in a correct way…we understood what we were doing so we could learn more about insects" (Student C,2). Additionally, student (C,4) distinguished the *realness* of the interactions between students and scientists, "…they were actually interacting with us…it didn't seem like a computer program answering questions."

Students in the control group reported significantly more interest in insects than the experimental group in the study. According to the study design protocol, students in the experimental group had to interact with the insects during the collection process while students in the control group only interacted with the insects through the Internet. Students in both groups generally stated that they had a low interest in insects before the remote investigation (control mean = 2.5 out of 6.0; experimental mean = 2.75 out of 6.0) in which many students stated that insects are *gross* and *disgusting*. Previous research by Randler, Hummel, and Wüst-Ackermann (2013) documented university students' emotion of *disgust* while interacting with live animals and prepared microscope slides in science labs. The findings indicated that the emotion of *disgust* was negatively correlated with interest. In this study, because high school students in the experimental group were subjected to interacting and collecting live insects that they perceived as *gross* and *disgusting*, their interest in insects throughout the investigation was much lower than the students in the control group.

Differences in Students' Reported Interactions and Distractions during the Remote Investigation

The construct, *virtual presence*, included four factors: control, sensory, distractions, and realism. Overall, students' reported perceptions of these constructs were not significantly different across treatment groups. However, there were individual items that were different between the control and experimental group. These included:

1. The control group was more likely to report that the program would respond to their manipulations than the experimental group.

2. The control group was more likely to report that it was easy to chat with the scientists through the chat box during the investigation.

3. The control group reported being more distracted by sounds and other events during the remote investigation.

4. The experimental group reported that they could concentrate easier during the session, and they were significantly less confused by the scientists.

While the overall virtual presence constructs were not significantly different between the control and experimental groups, the interview data showed there were subtle differences in the students' perceptions of *ownership of data*. The trend in the aforementioned data suggested that students in the experimental group that had the opportunity to choose their own insect were more attentive and had higher concentration levels during the investigation because it was *their insect* they were viewing. However, the control group may not have had the opportunity to *buy into* or *take ownership* of the program. Overall, the control group students' thought the program was interesting, but it was more of a *fun project* in which they did not invest their time selecting an insect to view. During the interviews, students in the control group stated how *cool* and *interesting* to see insects with the scanning electron microscope; however, students in the experimental group often made statements regarding how *different their insect was to other groups' insects*, the *type of questions they asked the scientists*, and how they want *to know more about their insect*. Student (E,2) stated "…we examined our insects…and we asked [the scientists] questions…the fact that somebody that actually studied in that field can help us out while we were examining our bugs." *Ownership of data* may have implications in engagement and supporting learning and interest in science during remote investigations.

Realness of Remote Investigations

How *real* the remote investigation is a construct of virtual presence that describes the participants' perception of the authenticity of the interactions between the participants, the technology, and the scientists in the remote investigation. Interestingly, teachers and students had different views on the *realness* of the remote investigation. Teachers were asked to describe the *realness* of the *Virtual Microscopy Lab* remote investigation. The teachers stated that there was a *disconnect* between the students and the scanning electron microscope because the Internet mediated the interactions between the students and the investigation. One teacher stated that "It felt it was real, in a sense, in that the kids could view insects with a microscope they would not have been able to do ever before. But, they were not actually using the microscope at the facility in person." The teachers defined *realism* in this context as the students being located in the lab with the scanning electron microscope. Because the Internet was perceived as a *mediator*, teachers did not report the remote investigation as *real*.

Students, however, reported the *realism* of the remote investigation as being genuinely real. Students' reported perceptions of the *realism* construct in virtual presence survey were above average. Throughout the student interviews, both control and experimental students perceived the remote investigation as *real*. Student remarks are listed below:

-"…it was like…I was there! I was doing this myself!" (Student C,1)

-"Very real, even though it was on the computer, it was real. We were doing it ourselves." (Student C,2)

-"It felt like the bug was sitting on the computer!" (Student C,3)

-"It was like I was actually looking into a microscope!" (Student E,2)

-"…everything felt like I was actually in the lab!" (Student E, 5)

The divide between students' and teachers' perception of *realness* in a remote investigation may be the difference in how each group interacted with the technology. The teachers' were *outsiders* watching the students use the technology; however, the students were physically interacting with the remote program (selecting images, changing magnification, chatting with the scientists). The students' engagement and interaction with the technology and the collaboration between the students and the scientists during the remote investigation may have affected the students' perception of *realism* in contrast to the perception of the teachers.

Three Emerging Constructs in Remote Investigations: Science Learning Drive, Environmental Presence, and Inner Realism Presence

As indicated by a review of literature, motivation, science identity, and virtual presence were specified as being vital for student learning and interest in science during remote investigations and virtual simulations. Each construct was further divided into multiple factors:

1. Motivation: Autonomy, Competence, and Relatedness

2. Identity: Performance, Competence, and Recognition

3. Virtual Presence: Control, Sensory, Distraction, and Realism

According to the exploratory factor analyses, the relationships between the constructs during the *Virtual Microscopy Lab* remote investigation were interrelated, creating new constructs that describe the relationships of motivation, identity, and presence in remote investigations. The three new constructs that were identified were *Science Learning Drive*, *Environmental Presence*, and *Inner Realism Presence*. *Science Learning Drive* construct incorporated *performance* and *competence* of science identity and *intrinsic motivation* factors. Students reporting a higher *Science Learning Drive* during a remote learning environment may have perceived themselves as having higher self-efficacy which may inspire, encourage, and motivate students' innate drive to learn science.

The construct, *environmental presence*, integrates *control*, *sensory*, and *distraction* factors of virtual presence in conjunction with *relatedness* motivation variable. *Environmental Presence* described students' perception of how physical interactions with the technology and the immediate environment, such as classmates, may influence how the students relate to the scientists during a remote investigation.

Environmental Presence may also be mediated by students' perception of *ownership* because students' that engaged in collecting insects during the *Virtual Microscopy Lab* remote investigation may have altered how students' perceive the relationship between them and the scientists. One interpretation of the results found here is that students collecting data may have felt a closer association with the scientists and thus may report fewer distractions during a remote investigation. A student in the experimental group stated "…it felt like I was actually in the lab. I believed I made a connection with the [scientists] because of…our tone…how we spoke to one another…I was able to freely ask questions about everything" (Student E,5).

Inner Realism Presence construct is composed of associations between the virtual presence factor, *realism*, and science identity variable, *recognition*. Based on student interviews and survey data, students reported the remote investigation as being *real*. Remote investigations may influence students' to want to be recognized as science-oriented individuals because the students perceived that they are in a *real* science laboratory. If the environment appears to be *real*, students may be driven by a sense of self-satisfaction in that they are recognized as a science-oriented individual because the students believe that their investigations mimic the actions of scientists.

The revised *remote environment learning model* demonstrates the complex associations between important variables that contribute to students' interest in science. There is a need for future studies to investigate other factors that contribute to successful remote investigation experiences for students, such as engagement, revised view of *ownership of data* and how students' perceptions of *ownership of data* influences their interactions in remote investigation, how remote technology is incorporated into science classrooms, and the connection of the use of remote technologies as a tool in K-12 environments to ignite an interest in science.

Additional studies are needed to examine specific points of control and *ownership* in remote investigations, students' interest, attitudes, and perception of objects investigated during the use of remote technologies, differences in students' and teachers' perceptions of *realness* during remote investigations, students' perceptions of group dynamics, and extending and scaling the experience for individual student opportunities during the remote investigation. This study focused on one aspect of ownership which detailed students' perception of ownership in connection with the insect they selected and submitted to the scientists. However, there are other forms of ownership or control throughout the study that may contribute to students' views of ownership such as manipulating the controls during the remote investigation or asking questions to the scientists. These other forms of ownership may influence students' interactions during a remote investigation. Additionally, understanding students' prior experiences, interest, attitudes, and perceptions of objects investigated, such as insects, may influence students' interactions. In this study, students in the experimental group that interacted with insects during the selection phase reported being significantly less interested in insects than the control students' during the remote investigation. Future studies could examine the influence of students' perceptions of other objects (e.g. planets) and prior experiences during a remote investigation (e.g. remote telescope) to see how the remote learning context influences perceptions of the learning experience. Furthermore, ideas for future studies could examine students' and teachers' perceptions of *realism* during a remote investigation. The differences in perceptions could alter how teachers present content and situate the structure of the classroom which may influence students' motivation and recognition during a remote investigation. Group dynamics should be investigated further to determine if there is a group effect that influences students' interactions, sense of control and ownership, and distraction factors. It is possible that scaling the model for individual student experiences instead of groups may influence how students interact in a remote learning environment; however, additional factors, such as technology constraints, timing and state tests, classroom structure, and partnering scientists/laboratories may also affect how remote learning environments are utilized in the classroom. Furthermore, this study should be replicated with larger sample sizes to more fully document student learning in remote learning environments.

> *"[The insects] are these little things that are complex…these little creatures are the size of your fingernails. I think every school in America should be able to do participate in [the Virtual Microscopy Lab] because it was awesome, and it was really fun." (Student C,1)*

By envisioning how technology will impact future scientific revolutions and the global workforce, it is imperative for teachers to enable their students to interact with technologies to prepare the students to become science-oriented and technologically-oriented citizens. According to the Next Generation Science Standards, there is a push for students to understand that there is an interdependence of science, engineering, and technology disciplines in which technology enables scientific discoveries by scientists and engineers ("Science, Technology, Society and the Environment," 2013). Because of the new advancements in technology that will affect how society interacts with the environment, teachers need to prepare students to be effective, science-educated individuals that will be able to make evidence-based decisions on the future of the impact of technology in the world. The use of virtual tools, such as remote technologies in science classrooms, will enable students to interact with research-grade tools, communicate with scientists and researchers, and develop awareness of the impact and importance of technology on scientific discoveries and the human condition.

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APPENDICES

Appendix A

Surveys

A.1 Prettest

Part I: Demographics

1. Gender: (Circle One Below):

   a. Female

   b. Male

2. Age: ________________

3. Ethnicity: (Circle One Below):

   a. American Indian or Alaskan Native

   b. Asian or Pacific Islander

   c. Black, not of Hispanic origin

   d. Hispanic

   e. White, not of Hispanic origin

   f. Other

   g. I wish not to report

4. On a scale of 1-5 (1 being low and 5 being high), how interesting are insects to you?

5. Have you ever collected insects? (Yes or No)

6. Have you caught insects while outdoors? (Yes or No)

7. Do you have insect(s) as pets? (Yes or No)

8. Have you ever watched television programs about insects? (Yes or No)

9. Have you read about insects on the internet? (Yes or No)

10. Have you taken video or pictures of insects? (Yes or No)

11. If you had the opportunity, would you like to visit a museum that had a butterfly house or an insect zoo with live insects? (Yes or No)

Part II: Prior Technology Use

Do you have **daily access** with the following:

1. Computer (circle one): Yes No

2. Internet (circle one): Yes No

3. How often do you use the following technologies/programs?

Technology	Never	Rarely	Sometimes	Always
Computer/Laptop				
Internet				
Use forums/post information on a website				
Submit data to an online web source or website				
Upload images/photos/videos to websites				
iPad/Netbooks				
Download scientific				

data from a website				
Telescope				
Microscope				

Part III: Motivation Survey

Directions: Read each statement carefully. Please write the number on the line provided next to the question that best represents how you feel when participating in the online science project.

Strongly Disagree	*Disagree*	*Slightly Disagree*	*Slightly Agree*	*Agree*	*Strongly Agree*
1	**2**	**3**	**4**	**5**	**6**

Intrinsic Motivation Questions:

_____1. Learning about science is interesting.

_____2. I am curious about discoveries in science.

_____3. I do not enjoy learning about insects.

_____4. The science I learn is relevant to my life.

_____5. Learning science makes my life more meaningful.

_____6. I enjoy learning science.

_____7. Learning about insects is interesting.

Career Motivation Questions:

_____8. Learning science will help me get a good job.

_____9. Understanding science will benefit me in my career.

_____10. Knowing science will give me a career advantage.

_____11. I will use science problem-solving skills in my career.

_____12. My career will involve science.

Self-Determination:

______13. I study hard to learn science.

______14. I prepare well for science tests and labs.

______15. I put enough effort into learning science.

______16. I spend a lot of time learning science.

______17. I use strategies to learn science well.

Part IV: Science Identity Survey

Directions: Read each statement carefully. Please write the number on the line provided next to the question that best represents how you feel when participating in the online science project.

Strongly Disagree	*Disagree*	*Slightly Disagree*	*Slightly Agree*	*Agree*	*Strongly Agree*
1	**2**	**3**	**4**	**5**	**6**

Performance:

______1. Doing science is important to who I am.

______2. I enjoy doing science.

______3. I expect to do well in science class this year.

______4. I am satisfied with my grades in science class.

______5. I am proud of my accomplishments in science class.

______6. I am afraid that I am not a good student in science.

Competence:

______1. My science knowledge and skills will allow me to help others.

______2. I am able to learn science well.

______3. I feel that I can't do a good job in science.

______4. I am sure of myself when I do science.

______5. I would consider a career in science.

_____6. I know I can do well in science.

_____7. I can do advanced work in science.

_____8. I am confident that I can understand science.

Relatedness:

_____1. I identify as a scientist.

_____2. My peers recognize me as a scientist.

_____3. My teacher recognizes me as a scientist.

_____4. It is important to me that others see me as a scientist.

Part V: Content Survey

1. Label the following *Drosophila melanogaster* body parts (a-e) in the diagram below.

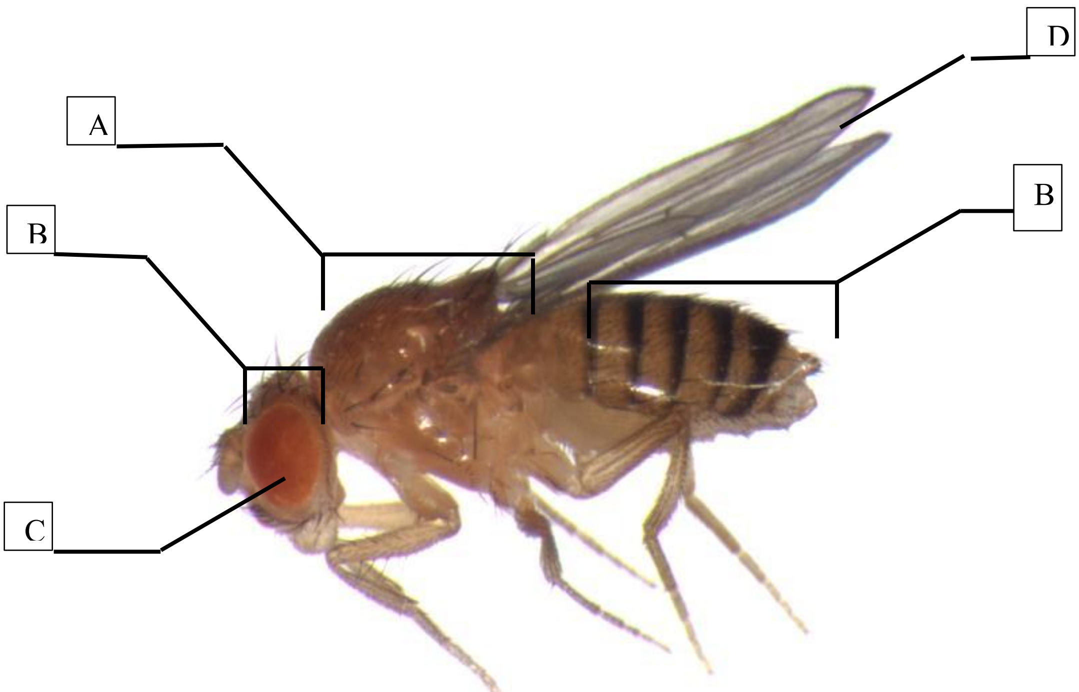

Image taken from: http://www.uamont.edu/facultyweb/stewartm/GeneticsPages/fly.JPG

2. The arrows are pointing to structures that allows for gas exchange in *Drosophila melanogaster* and other insects. Label the structure (a) in the diagram below.

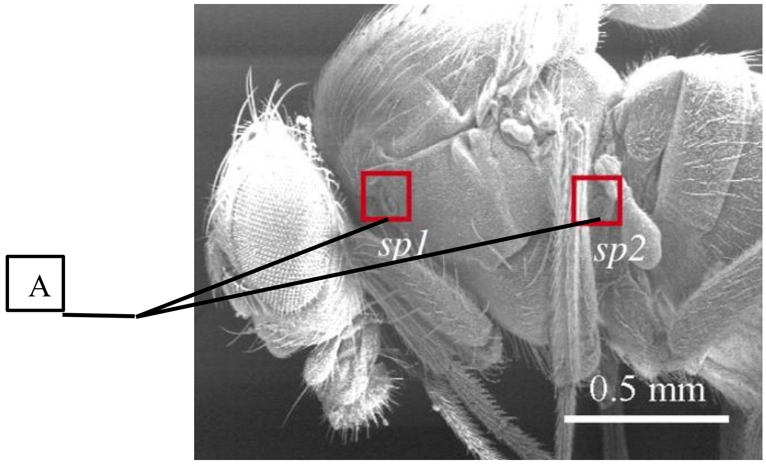

Image taken from: http://jeb.biologists.org/content/209/9/1662/F1.large.jpg

3. The arrows are pointing to ... *stor* to be able to sense (feel, hear, and taste) their surroundings. Label the structure (a) in the diagram below.

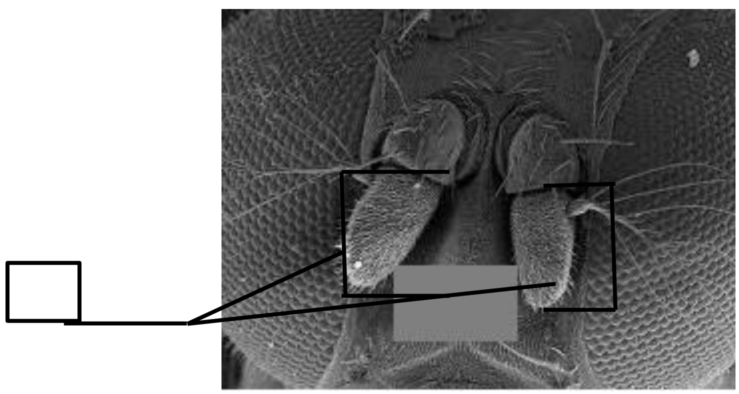

Image taken from: http://ucanr.edu/blogs/bugsquad/blogfiles/3736.jpg

4. What are the main body sections of an insect?

a. Head, Thorax, Tail

b. Head, Tail

c. Head, Abdomen, Tail

d. Head, Thorax, Abdomen

5. What is the name of the external skeleton that helps support and protects insects?

a. Shell

b. Endoskeleton

c. Exoskeleton

d. Pod

6. The field of scientific study of insects is known as:

a. Botany

b. Entomology

c. Ecology

d. Pathology

7. Which kingdom do insects belong to?

a. Animalia

b. Plantae

c. Fungi

d. Protista

8. What is a difference between a compound light microscope and a scanning electron microscope?

a. Compound light microscopes have a lens made of glass and uses light to illuminate and magnify a specimen whereas scanning electron microscopes use a beam of electrons to magnify a specimen.

b. Compound light microscopes use water molecules and a glass lens to illuminate and magnify a specimen whereas scanning electron microscopes use a beam of electrons to magnify a specimen.

c. Scanning electron microscopes has a lens made of glass and uses light to illuminate and magnify a specimen whereas compound light microscopes use a beam of electrons to magnify a specimen.

d. Scanning electron microscopes use water molecules and a glass lens to magnify specimens whereas compound light microscopes have a lens made of glass and uses light to illuminate and magnify a specimen.

9. What is a typical magnification range of a scanning electron microscope?

a. centimeter to meter

b. micrometer to kilometer

c. millimeter to decimeter

d. nanometer to millimeter

10. What is the approximate size of *Drosophila melanogaster*?

a. 1-3 micrometers

b. 1-3 millimeters

c. 1-3 centimeters

d. 1-3 meters

11. What material makes up the external skeleton of an insect?

a. chitin

b. wax

c. protein

d. enamel

12. Insects have ________ legs, which are attached to the ________ body part.

a. 8, thorax

b. 6, tail

c. 6, thorax

d. 8, tail

A.2 Posttest

Part 1: Motivation Survey

Directions: Read each statement carefully. Please write the number on the line provided next to the question that best represents how you feel when participating in the online science project.

Strongly Disagree	*Disagree*	*Slightly Disagree*	*Slightly Agree*	*Agree*	*Strongly Agree*
1	**2**	**3**	**4**	**5**	**6**

Intrinsic Motivation Questions:

_____1. Learning about science is interesting.

_____2. I am curious about discoveries in science.

_____3. I do not enjoy learning about insects.

_____4. The science I learn is relevant to my life.

_____5. Learning science makes my life more meaningful.

_____6. I enjoy learning science.

_____7. Learning about insects is interesting.

Career Motivation Questions:

_____8. Learning science will help me get a good job.

_____9. Understanding science will benefit me in my career.

_____10. Knowing science will give me a career advantage.

_____11. I will use science problem-solving skills in my career.

_____12. My career will involve science.

Self-Determination:

_____13. I study hard to learn science.

_____14. I prepare well for science tests and labs.

_____15. I put enough effort into learning science.

_____16. I spend a lot of time learning science.

_____17. I use strategies to learn science well.

_____18. I feel obligated to work on the *Virtual Microscopy Lab* computer program.

_____19. I believe I am able to complete the activities with *Virtual Microscopy Lab* computer program.

_____20. The *Virtual Microscopy Lab* scientists did not allow me to investigate freely within the *Virtual Microscopy Lab* computer program.

_____21. I have a choice in choosing what I want to learn with *Virtual Microscopy Lab* computer program.

_____22. I have to force myself to complete the activities within *Virtual Microscopy Lab* computer program.

_____23. I have a say in what I want to explore in *Virtual Microscopy Lab* computer program.

_____24. I feel that I am able to interact freely with the *Virtual Microscopy Lab* scientists.

_____25. I believe that I am able to freely ask questions with the *Virtual Microscopy Lab* scientists.

_____26. The *Virtual Microscopy Lab* scientists encouraged me to explore the activities within *Virtual Microscopy Lab* computer program.

Part II: Presence Survey

Directions: Read each statement carefully. Please write the number on the line provided next to the question that best represents how you feel when participating in the online science project.

Strongly Disagree	*Disagree*	*Slightly Disagree*	*Slightly Agree*	*Agree*	*Strongly Agree*
1	**2**	**3**	**4**	**5**	**6**

_____ 1. I was in control when participating in the *Virtual Microscopy Lab* session.

_____ 2. The *Virtual Microscopy Lab* computer program would respond to my directions.

_____ 3. My sense of sight was highly engaged when participating in the *Virtual Microscopy Lab* session.

_____ 4. My sense of hearing was highly engaged when participating in the *Virtual Microscopy Lab* session.

_____ 5. My sense of touch was highly engaged when participating in the *Virtual Microscopy Lab* session.

_____ 6. All my senses were engaged when participating in the *Virtual Microscopy Lab* session.

_____ 7. My interactions with the *Virtual Microscopy Lab* computer program were natural and easy.

_____ 8. When participating in the *Virtual Microscopy Lab* session, I was aware of other events occurring around me.

_____ 9. When participating in the *Virtual Microscopy Lab* session, I was aware of the computer program I was using.

_____ 10. When participating in the *Virtual Microscopy Lab* session, I was aware of other sounds around me.

_____ 11. When participating in the *Virtual Microscopy Lab* session, I was aware of the *Virtual Microscopy Lab* scientists.

_____ 12. When participating in the *Virtual Microscopy Lab* session, I could tell where other sounds were coming from.

_____ 13. I enjoyed controlling the *Virtual Microscopy Lab* website.

_____ 14. I was able to move around in the *Virtual Microscopy Lab* website with ease.

_____ 15. I was able to chat easily with the *Virtual Microscopy Lab* scientists through the chat window.

_____ 16. I can easily manipulate the *Virtual Microscopy Lab* computer program in any way I want.

_____ 17. I could transition from the real world to using the *Virtual Microscopy Lab* computer program.

_____ 18. I was able to interact easily with the *Virtual Microscopy Lab* computer program.

_____ 19. I was easily distracted when participating in the *Virtual Microscopy Lab* computer program.

_____ 20. The *Virtual Microscopy Lab* scientists distracted me when I was using the *Virtual Microscopy Lab* computer program.

_____ 21. The *Virtual Microscopy Lab* computer program I used distracted me from learning.

_____ 22. I can concentrate easily while participating with the *Virtual Microscopy Lab* computer program.

_____ 23. I lost track of time when participating in the *Virtual Microscopy Lab* session.

_____ 24. I quickly adjusted to using the *Virtual Microscopy Lab* computer program.

_____ 25. The *Virtual Microscopy Lab* scientists did not confuse me during the learning session.

Part III: Science Identity Survey

Directions: Read each statement carefully. Please write the number on the line provided next to the question that best represents how you feel when participating in the online science project.

Strongly Disagree	*Disagree*	*Slightly Disagree*	*Slightly Agree*	*Agree*	*Strongly Agree*
1	**2**	**3**	**4**	**5**	**6**

Performance:

______ 1. Doing science is important to who I am.

______ 2. I enjoy doing science.

______ 3. I expect to do well in science class this year.

______ 4. I am satisfied with my grades in science class.

______ 5. I am proud of my accomplishments in science class.

______ 6. I enjoyed using the *Virtual Microscopy Lab* program to learn about insects.

______ 7. I am afraid that I am not a good student in science.

______ 8. I could easily use the *Virtual Microscopy Lab* tools to view the insect.

Competence:

______ 1. My science knowledge and skills will allow me to help others.

______ 2. I am able to learn science well.

______ 3. I feel that I can't do a good job in science.

_____ 4. I feel confident that I learned a lot about insects while using the *Virtual Microscopy Lab* program.

_____ 5. I am sure of myself when I do science.

_____ 6. I would consider a career in science.

_____ 7. I know I can do well in science.

_____ 8. I can do advanced work in science.

_____ 9. I am confident that I can understand science.

Relatedness:

_____ 1. I identify as a scientist.

_____ 2. My peers recognize me as a scientist.

_____ 3. My teacher recognizes me as a scientist.

_____ 4. It is important to me that others see me as a scientist.

_____ 5. I can relate to the *Virtual Microscopy Lab* scientists.

Part IV: Interest Survey

1. On a scale of 1-5 (1 being low and 5 being high), how interesting are insects to you?

2. On a scale of 1-5 (1 being low and 5 being high), how interesting was *Virtual Microscopy Lab* to you?

3. Do you want to collect insects after participating in the *Virtual Microscopy Lab* session? **Why or why not?**

4. Do you want to have insect(s) as pets after participating in the *Virtual Microscopy Lab* session? **Why or why not?**

5. If you had the opportunity, would you like to visit a museum that had a butterfly house or an insect zoo with live insects? **Why or why not?**

6. Would you like to participate in another *Virtual Microscopy Lab* session? **Why or why not?**

7. What did you like about the *Virtual Microscopy Lab* session?

8. What did you **NOT** like about the *Virtual Microscopy Lab* session?

9.. Would you recommend other students to participate in future *Virtual Microscopy Lab* sessions during science class? **Why or why not?**

10. Would you like to participate in other interactive online learning sessions, such as learning about astronomy by controlling telescopes or about viruses by controlling a microscope in the future? **Why or why not?**

11. Do you think it is important for students to choose and view their own insect when participating in the *Virtual Microscopy Lab* project? **Why or why not?**

12. Would you be willing to collect your own scientific data and submit it to a scientific organization? **Why or why not?**

12. Do you think it is important for students to be able to communicate with the scientists during *Virtual Microscopy Lab*? **Why or why not?**

13. Is there anything else you would like to share with me about your experience?

Part V: Content Survey

1. Label the following *Drosophila melanogaster* body parts (a-e) in the diagram below.

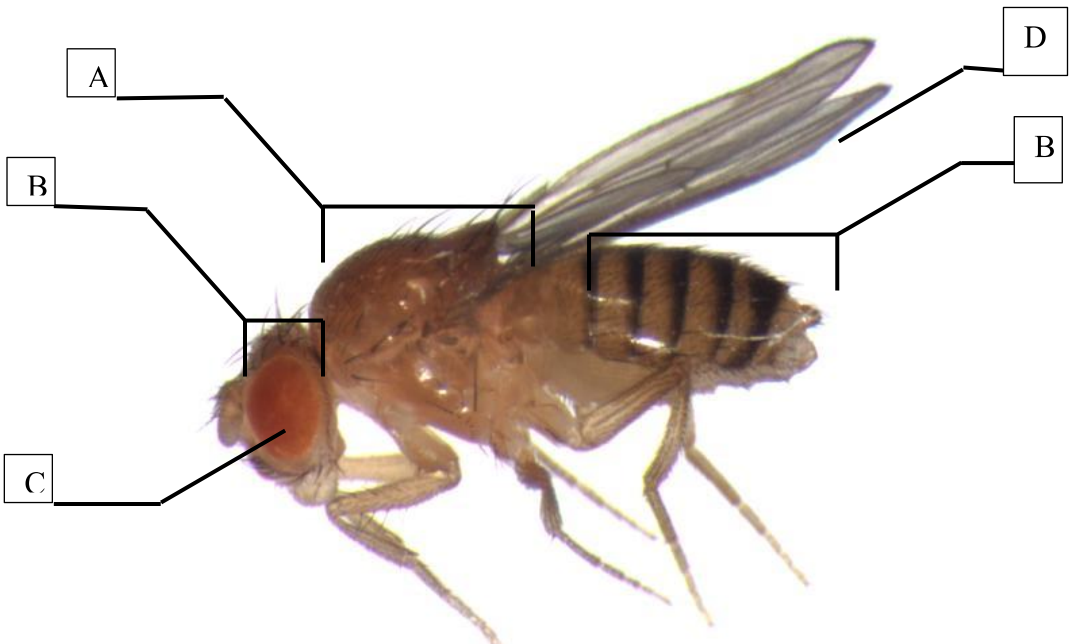

Image taken from: http://www.uamont.edu/facultyweb/stewartm/GeneticsPages/fly.JPG

2. The arrows are pointing to structures that allows for gas exchange in *Drosophila melanogaster* and other insects. Label the structure (a) in the diagram below.

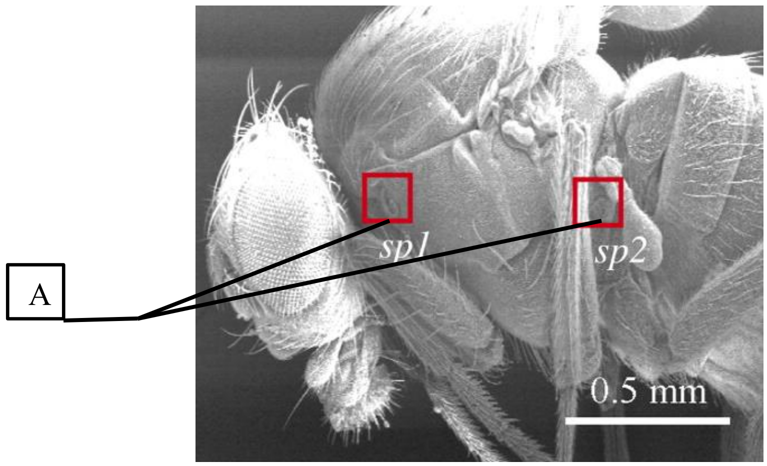

Image taken from: http://jeb.biologists.org/content/209/9/1662/F1.large.jpg

3. The arrows are pointing to structures that aid *Drosophila melangastor* to be able to sense (feel, hear, and taste) their surroundings. Label the structure (a) in the diagram below.

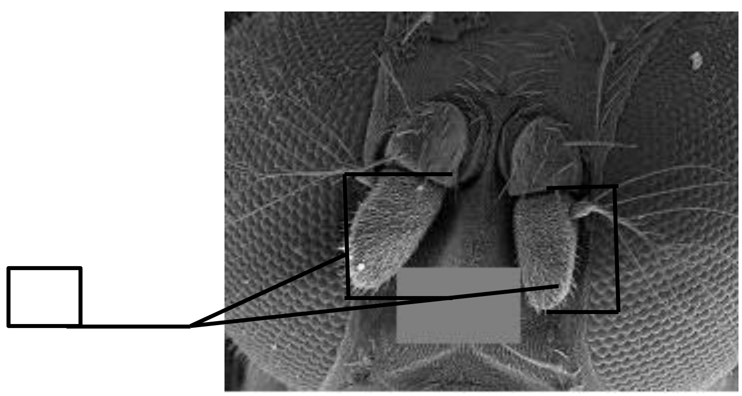

Image taken from: http://ucanr.edu/blogs/bugsquad/blogfiles/3736.jpg

4. What are the main body sections of an insect?

a. Head, Thorax, Tail

b. Head, Tail

c. Head, Abdomen, Tail

d. Head, Thorax, Abdomen

5. What is the name of the external skeleton that helps support and protects insects?

a. Shell

b. Endoskeleton

c. Exoskeleton

d. Pod

6. The field of scientific study of insects is known as:

a. Botany

b. Entomology

c. Ecology

d. Pathology

7. Which kingdom do insects belong to?

a. Animalia

b. Plantae

c. Fungi

d. Protista

8. Which type of microscope was used to view the insects in *Virtual Microscopy Lab*?

a. Compound Light Microscope

b. Transmission Electron Microscope

c. Scanning Electron Microscope

d. Atomic Force Microscope

9. What is a difference between a compound light microscope and a scanning electron microscope?

a. Compound light microscopes have a lens made of glass and uses light to illuminate and magnify a specimen whereas scanning electron microscopes use a beam of electrons to magnify a specimen.

b. Compound light microscopes use water molecules and a glass lens to illuminate and magnify a specimen whereas scanning electron microscopes use a beam of electrons to magnify a specimen.

c. Scanning electron microscopes has a lens made of glass and uses light to illuminate and magnify a specimen whereas compound light microscopes use a beam of electrons to magnify a specimen.

d. Scanning electron microscopes use water molecules and a glass lens to magnify specimens whereas compound light microscopes have a lens made of glass and uses light to illuminate and magnify a specimen.

10. What is a typical magnification range of a scanning electron microscope?

a. centimeter to meter

b. micrometer to kilometer

c. millimeter to decimeter

d. nanometer to millimeter

A.3 Delayed Posttest

Delayed Post-Survey

Directions: Read each statement carefully. Please write the number on the line provided next to the question that best represents how you feel when participating in the online science project.

Strongly Disagree	*Disagree*	*Slightly Disagree*	*Slightly Agree*	*Agree*	*Strongly Agree*
1	**2**	**3**	**4**	**5**	**6**

Intrinsic Motivation Questions:

_____1. Learning about science is interesting.

_____2. I am curious about discoveries in science.

_____3. I do not enjoy learning about insects.

_____4. The science I learn is relevant to my life.

_____5. Learning science makes my life more meaningful.

_____6. I enjoy learning science.

_____7. Learning about insects is interesting.

Career Motivation Questions:

_____8. Learning science will help me get a good job.

_____9. Understanding science will benefit me in my career.

_____10. Knowing science will give me a career advantage.

______11. I will use science problem-solving skills in my career.

______12. My career will involve science.

Self-Determination:

______13. I study hard to learn science.

______14. I prepare well for science tests and labs.

______15. I put enough effort into learning science.

______16. I spend a lot of time learning science.

______15. I use strategies to learn science well.

Interest Questions:

17. On a scale of 1-5 (1 being low and 5 being high), how interesting are insects to you?

18. Did you collect insects after participating in the *Virtual Microscopy Lab* session? **Why or why not?**

19. Do you now have insect(s) as pets after participating in the *Virtual Microscopy Lab* session? **Why or why not?**

20. Do you have insect(s) as pets after participating in the *Virtual Microscopy Lab* session? **Why or why not?**

21. Since participating in the *Virtual Microscopy Lab* session, did you watch television programs about insects? **Why or why not?**

22. Since participating in the *Virtual Microscopy Lab* session, have you read about insects on the internet? **Why or why not?**

23. Since participating in the *Virtual Microscopy Lab* session, have you taken video or pictures of insects? **Why or why not?**

24. If you had the opportunity, would you like to visit a museum that had a butterfly house or an insect zoo with live insects? **Why or why not?**

Appendix B

Interview Protocols

B.1 Teacher Interview Protocol

Teacher Interview Code: ______________________

1. What are the benefits of a remote investigation for teaching science?

2. What are the constraints of a remote investigation for teaching science?

3. What are the benefits of *Virtual Microscopy Lab*?

4. What are the constraints of *Virtual Microscopy Lab*?

5. Do you think it is important for your students to have the opportunity to choose their own insect?

6. How real was the *Virtual Microscopy Lab* session to you?

7. Do you believe it is important for students to be able to communicate with scientists during a remote investigation?

8. Do you believe it is important for students to be able to communicate with scientists to learn science?

9. Any other thoughts, questions, or comments about the usefulness of a remote investigation program like *Virtual Microscopy Lab*?

B.2 Control Interview Protocol

Part I: Ownership Interview (Control)

1. Did you control or change the settings to view the insects in a different way?

2. Did you have questions about the insects? Did you ask the scientist? Did the scientist satisfactorily answer your question?

3. Did you give the insect(s) a name?

4. What kind of feelings did you have when you saw the insects on the screen?

5. Did you feel that other students took time away from you while you were viewing the insects during the *Virtual Microscopy Lab* session?

6. After the *Virtual Microscopy Lab* session, who do you feel should keep the insects?

7. Do you think it would be more interesting to look at an insect you personally collected and gave to the *Virtual Microscopy Lab* scientists?

8. In the future, would you prefer to look at an insect you collect or look an insect chosen by your teacher?

Part II: General Interview

1. How interested are you in science? Which aspects of science do you find interesting? Which aspects of science do you find uninteresting?

2. What do you see yourself doing after you finish school (career and education)? What about that future career interests you? (If not science-related: Could you possibly see yourself doing a science-related career?)

3. Have you learned about insects before? (If yes: Tell me about it).

4. Describe your experiences with *Virtual Microscopy Lab*. Was it interesting?

5. Did you experience any problems (learning or participating) during the *Virtual Microscopy Lab* session?

6. Did you feel like you understood what was going on?

7. Do you see yourself as a scientist? Why or why not?

8. Do you think your teacher or your peers see you as a science-oriented person?

9. Do you think you could be like one of the *Virtual Microscopy Lab* scientists? Why or why not?

10. Do you like to learn about science? Why?

11. Do you find it easy or hard to learn science? Why?

12. Do you think it is important to learn about science?

13. What was your learning goal for this learning session?

14. Did you feel that you could do what you want while observing the insect during the *Virtual Microscopy Lab* session?

15. Did you feel that you made a connection with the scientist? Were you freely able to ask the scientists questions during the session?

16. How real did the *Virtual Microscopy Lab* session appear to you?

17. Did you feel like you were right beside the scientists during the session?

18. Did you lose track of time during the *Virtual Microscopy Lab* session?

19. Was it easy to use the controls during the *Virtual Microscopy Lab* session?

20. Did anything distract you from participating fully during the *Virtual Microscopy Lab* session

21. Do you think that you will want to continue to learn about insects? Why or why not?

B.3 Experimental Interview Protocol

Part I: Ownership Interview (Experimental)

1. When the class was able to view the insects, how did you know which insect was the one you and your group collect?

1. Did you control or change the settings to view your insect in a different way?

2. Did you have questions about your insect? Did you ask the scientist? Did the scientist satisfactorily answer your question?

3. Did you or your group name your insect?

4. What kind of feelings did you have when you saw your insect on the screen?

5. Did you feel that other students took time away from you while you were viewing your insect?

6. After the *Virtual Microscopy Lab* session, who do you feel should keep the insect?

7. Was it more interesting to look at your insect or someone else's insect?

8. In the future, would you prefer to look at an insect you collect or look an insect chosen by your teacher?

Part II: General Interview

9. How interested are you in science? Which aspects of science do you find interesting? Which aspects of science do you find uninteresting?

10. What do you see yourself doing after you finish school (career and education)? What about that future career interests you? (If not science-related: Could you possibly see yourself doing a science-related career?)

11. Have you learned about insects before? (If yes: Tell me about it).

12. Describe your experiences with *Virtual Microscopy Lab*. Was it interesting?

13. Did you experience any problems (learning or participating) during the *Virtual Microscopy Lab* session?

14. Did you feel like you understood what was going on?

15. Do you see yourself as a scientist? Why or why not?

16. Do you think your teacher or your peers see you as a science-oriented person?

17. Do you think you could be like one of the *Virtual Microscopy Lab* scientists? Why or why not?

18. Do you like to learn about science? Why?

19. Do you find it easy or hard to learn science? Why?

20. Do you think it is important to learn about science?

21. What was your learning goal for this learning session?

22. Did you feel that you could do what you want while observing your insect during the *Virtual Microscopy Lab* session?

22. Did you feel that you made a connection with the scientist? Were you freely able to ask the scientists questions during the session?

23. How real did the *Virtual Microscopy Lab* session appear to you?

24. Did you feel like you were right beside the scientists during the session?

25. Did you lose track of time during the *Virtual Microscopy Lab* session?

26. Was it easy to use the controls during the *Virtual Microscopy Lab* session?

27. Did anything distract you from participating fully during the *Virtual Microscopy Lab* session

28. Do you think that you will want to continue to learn about insects? Why or why not?