International Journal of Science Education

ISSN: 0950-0693 (Print) 1464-5289 (Online) Journal homepage: http://www.tandfonline.com/loi/tsed20

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To cite this article: Gina Childers & M. Gail Jones (2015) Students as Virtual Scientists: An exploration of students' and teachers' perceived realness of a remote electron microscopy investigation, International Journal of Science Education, 37:15, 2433-2452, DOI: 10.1080/09500693.2015.1082043

To link to this article: http://dx.doi.org/10.1080/09500693.2015.1082043

Published online: 11 Sep 2015.

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International Journal of Science Education, 2015
Vol. 37, No. 15, 2433–2452, http://dx.doi.org/10.1080/09500693.2015.1082043

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Students as Virtual Scientists: An exploration of students' and teachers' perceived realness of a remote electron microscopy investigation

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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. Very little is known about student perceptions of how real remote investigations are and how immersed the students are in the experience. This study, conducted with high school students and their teachers, explored the impact of students' perception of *ownership* and *virtual presence* during a remote investigation using a scanning electron microscope. Students were randomly assigned to one of two treatment groups: students able to select their own insect to use during the remote investigation, and students that did not select their own insects to view during the remote investigation. The results of this study showed that students in the experimental group who had choice and ownership of their insect reported being more present (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. Students indicated the remote investigation was *very real*; however, the teachers of these students were less likely to describe the investigation as being *real*. The results of this study have practical implications for designing remote learning environments.

Keywords: *Science education; Remote microscopy; Virtual presence; Ownership*

Introduction

> '[The remote learning session] was very real to me because I had full control over the way I wanted to look at the bugs. It felt like the bug was sitting on the computer!' (Student, C3)

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Remote learning environments offer unique learning experiences such as providing students with access to research tools or opportunities to communicate with scientists and researchers at different locations in the world. Students for the first time in history can become virtual researchers in scientists' laboratories. As a consequence of this access, the idea of student *ownership* 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 endeavors such as citizen science projects (Catlin-Groves, 2012). New virtual technologies blur the line between *real* and *simulated* learning environments. Although student learning with simulations has been studied for decades, there is a dearth of information about student perceptions of presence (defined here as perceptions of being present in a virtual environment) and ownership of experiments in remote learning systems (Childers & Jones, 2014; Corter, Esche, Chassapis, Ma, & Nickerson, 2011; Ma & Nickerson, 2006). There is some evidence that when students' perceive being present in a virtual environment, there are increased learning gains and student performance (Bystrom & Barfield, 1999; Hedley, Billinghurst, Postner, May, & Kato, 2002; Mikropoulos, 2006; Sheridan, 1992; Slater & Usoh, 1993; Steuer, 1992; Winn, Windschitl, Frauland, & Lee, 2002).

The advances in virtual and remote technologies have reached the point that students may not always perceive differences in real and virtual environments. For example, in a study of remote access with atomic force microscopy, Jones, Andre, Superfine, and Taylor (2003) found students were not able to discern real-time experimentation from simulated experimentation. This raises questions about how *real* remote investigations are to students. Does it matter if students analyze data they collect, or is it just as valuable to explore scientists' or teachers' data? There is evidence that inquiry done in school laboratories may be distinctly different than the inquiry processes that are used in scientists' inquiry (Chinn & Hmelo-Silver, 2002; Chinn & Malhotra, 2002) and now that students can investigate science (remotely) alongside scientists, there are new, unexplored questions about students' and teachers' perceptions of these investigations.

This study explored students' perception of ownership and virtual presence. The aim of this research study was to explore this relationship between students' perception of ownership of a remote electron microscopy lesson (*Remote Microscopy Lab*) and their perception of virtual presence. The research questions are addressed as follows:

1. Does student ownership of an investigation influence the perception of presence in a remote learning environment?
2. Are there differences in students' and teachers' perceived presence during a remote learning investigation?

Remote Learning Environments

Remote learning environments have the potential to enable students to engage in learning experiences that are important for learning science. Remote technology affords students' and teachers' access to scientific tools too costly for classroom use

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(scanning electron microscopes, telescopes, etc.) and opportunities to communicate with scientists through a network connection (Lowe, Newcombe, & Strumpers, 2013; Ma & Nickerson, 2006). During a remote investigation, students are able to conduct experiments, and engage in scientific inquiry: observe, question, collect, and analyze data, and interpret results at a distance from the laboratory (Lowe et al., 2013). Remote learning environments have the potential to engage students in science in innovative ways since technology use in science classrooms has been correlated with increased student interest in science as well in academic achievement overall (O'Day, 2007; Walsh, Sun, & Riconscente, 2011). Remote learning environments bridge the traditional gap between hands-on laboratories and computer simulations by providing students the opportunity to do science investigations at a distance from a scientific laboratory.

Although there are significant potential benefits by using remote learning environments in middle school and high schools, there is little research about student perceptions of these remote learning tools (Lowe et al., 2013). Most of the existing literature describes the design and implementation of remote access technology rather than the efficacy of the technology (Lowe et al., 2013; Ma & Nickerson, 2006). In addition, the remote access technology that is available is heavily biased towards engineering disciplines and college-level students (Ku, Ahfock, & Yusaf, 2011; Ma & Nickerson, 2006).

In one of the earlier studies, Jones et al. (2004) investigated 209 high school and middle school students' understandings 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 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 better attitudes about the experience 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 et al. (2003) studied 50 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 suggested that experiences with virtual technologies may be beneficial to students' engagement, motivation, and learning of science concepts.

Virtual Presence

Students engaged in remote learning experience access a laboratory environment by conducting experiments, using research tools, and communicating with scientists through virtual mediation while they are physically located in a different environment such as a classroom or computer lab in a school. One of the challenges of investigating science remotely is the degree to which the computer interface provides a learning experience. Presence is a term that describes how *real* a virtual environment is perceived by an individual. There are numerous definitions and views of virtual presence in research that span academic disciplines such as psychology, computer science, and engineering (Lombard & Ditton, 1997). Presence is often subdivided into other related terms (physical, telepresence, and virtual) designed to describe an individual's experience (Lee, 2004; Ma & Nickerson, 2006; Sheridan, 1992). Students commonly have educational experiences with computer simulations, but the degree to which students perceive real-time remote investigations with immediate feedback as under their control is not known. Witmer and Singer (1998) noted that control is one of the key factors that contributes to students' perception of presence (or realism). For the purpose of this study, *virtual presence* is the focus because 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 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 is the focus of 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 (Schifter, Ketelhut, & Nelson, 2012; Witmer & Singer, 1998). These conditions for presence are influenced by four factors that govern students' attention in a remote learning environment 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) is generated output of information processed 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, make choices, or participants' ability to interact freely with the scientists.
4. **Perception of realism** in a remote learning environment is the extent to which participants feel as if they were located in the virtual environment (in this case the scientists' research lab) instead of in the classroom. Vividness, connectedness, and meaningfulness of the remote learning environment are crucial for the perception of presence.

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Figure 1 shows a model of virtual presence factors in a remote learning system in which the instructional technology may be mediated by a teacher or instructor who ensures an appropriate connection is established between the student and the remote learning environment. The remote learning environment investigation 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 (Bystrom & Barfield, 1999; Hedley et al., 2002; Mikropoulos, 2006; Sheridan, 1992; Slater & Usoh, 1993; Steuer, 1992; Winn et al., 2002). However, the link between presence and learning has been questioned by other researchers. For example, researchers argue participants with a high level of perceived presence are already highly engaged within the learning environment (Scoresby & Shelton, 2011).

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 virtual presence within remote learning environments in school settings.

Ownership

Another area that has not been well researched is that of students' perceptions of ownership in science experiments and remote learning environments. In particular, how does having the choice and control of the objects under investigation influence

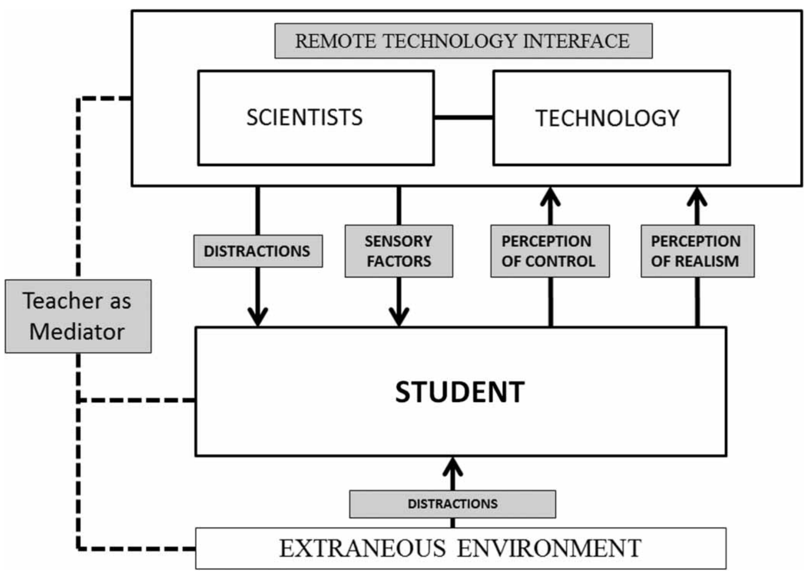

Figure 1. A model of the relationship of factors (distraction, sensory, control, realism) of presence in relation to the student and remote learning environment

students' perception of the *realness* of the experience? Ownership and choice in science investigations has the potential to enhance perceptions of control and engagement. The few studies that exist often address other forms of *ownership* as they pertain to education and learning. For instance, the research available focuses on student perception of ownership under the following circumstances: student perception of ownership of classroom structure, project ownership, business ownership and entrepreneurship, and students' perception of ownership and intellectual property rights in entrepreneurship capstone classes (Hanauer, Frederick, Fotinakes, & Strobel, 2012; O'Neill, 2010; Silvernagel, Schultz, Moser, & Aune, 2009; Van Auken, 2013).

O'Neill and Barton (2005) qualitatively investigated properties of students' *ownership* of learning throughout a science video project. Using 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 included:

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, 2005).

It is not yet clear how students' ownership of the aspects of the science investigation in virtual or remote learning environments influences their perception of presence (or realness). To explore the relationship between perceived virtual presence and ownership in remote learning investigations, the present study explored students' experiences, including perceived control, distractions, realism, and sensory factors in relationship to students' perception of ownership of the investigation.

Methodology

Research Design

Quantitative and qualitative measures were used to explore participants' perceived presence and ownership during a remote learning session with scanning electron microscopy. 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 session, *Remote Microscopy Lab*, which taught students about

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the anatomy and morphology of insects and microscopy (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 to investigate during the first remote learning session. The control group also investigated a *Drosophila*, but students were not given an opportunity to select a specific *Drosophila* to image and instead investigated a *Drosophila* provided by the scientists. Both the control and experimental group participated in a second remote learning session that enabled the participants to explore a variety of insects provided by the *Remote Microscopy Lab* scientists. Both session one (*D. melanogaster* viewing) and session two (variety of insects viewing) lasted for approximately 45 minutes. The survey design consisted of a post survey and an open-ended interview with students and teachers after the two remote learning sessions.

Study Site and Participants. The study was conducted at an urban high school in the southeastern United States. The high school had approximately 200 students enrolled in grades 9 through 12 with 46% of the population qualified for free/reduced lunch. The students ($n = 72$) were obtained from six of the nine biology and physical science classes (9th and 10th grade). 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. The six classes were randomly assigned to the control ($n = 36$) or the experimental group ($n = 36$). Consent to participate in the study was given by the participants and their parent or guardian to collect survey and interview data. Before the remote learning investigation commenced, participants were asked to report their prior experiences with technology and knowledge of insects. There were no substantial differences between the control group and experimental group participants. 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 *Remote Microscopy Lab*. All three teachers attended the two remote sessions with their classes. The three teachers were female, and the reported ethnicity of the teachers was African American, Caucasian, and Asian. 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. Ten students (5 control; 5 experimental) were randomly selected and interviewed after the *Remote Microscopy Lab* session to understand students' perceptions of ownership and virtual presence. Two female (both African American) and three male (two African American and one Caucasian) students were interviewed from the control group and three females (two African American and one Hispanic) and two males (both African American) were interviewed from the experimental group.

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Instructional Technology. *Remote Microscopy Lab* (a pseudonym) is a remote electron microscopy program hosted by a university located in the Midwest of the United States. Participants collect insects and send the insects through the mail to the *Remote Microscopy Lab* scientists. The insects are prepared and mounted on a stage by the scientists and are viewed with a scanning electron microscope.

The web-based *Remote Microscopy Lab* program allows participants to view the specimen, change the focus and magnification, communicate with the scientists in real-time through an online interactive chat module (shown in Figure 2), and to direct the scanning electron microscope to view a chosen insect and manipulate the image (shown in Figures 3 and 4).

The user interface on the main page of the *Remote 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 the image. The bottom displays the size and magnification for each image. Below the image, students are able to type in questions or comments to the scientists. In Figure 2, 'Station 8' included a group of students in the study that asked about the structures they were viewing on the main screen. In response, the scientists supplied information and answered the students' questions. To change the interface pages (described below), a blue control button with a white

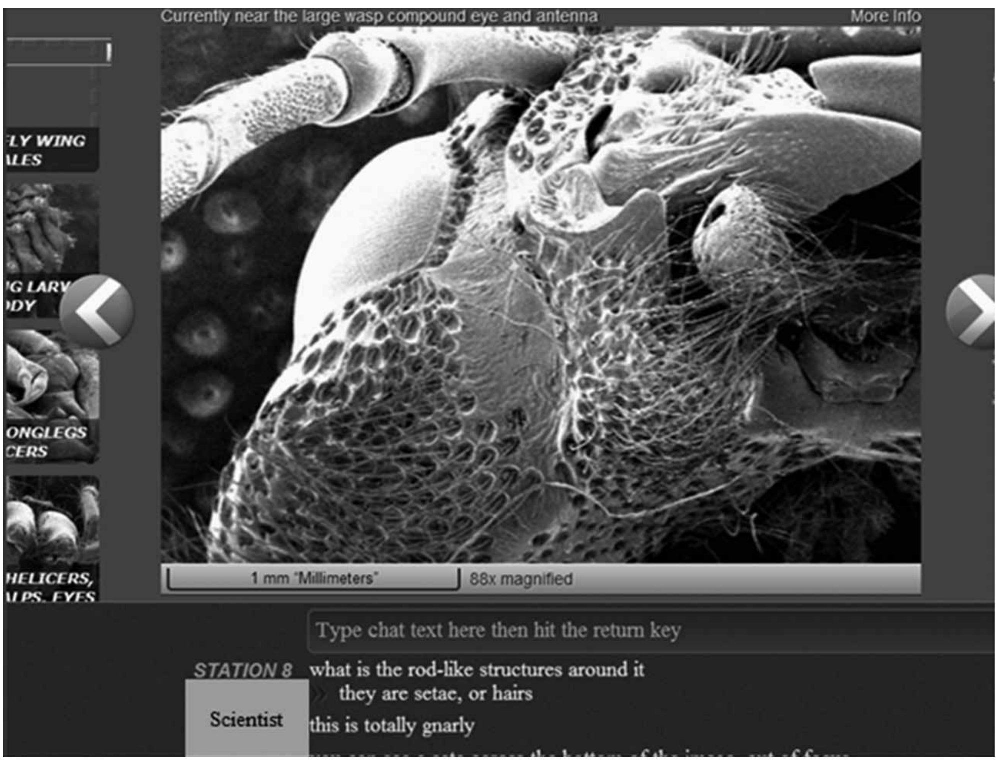

Figure 2. Screenshot of the main *Remote Microscopy Lab* interactive session screen

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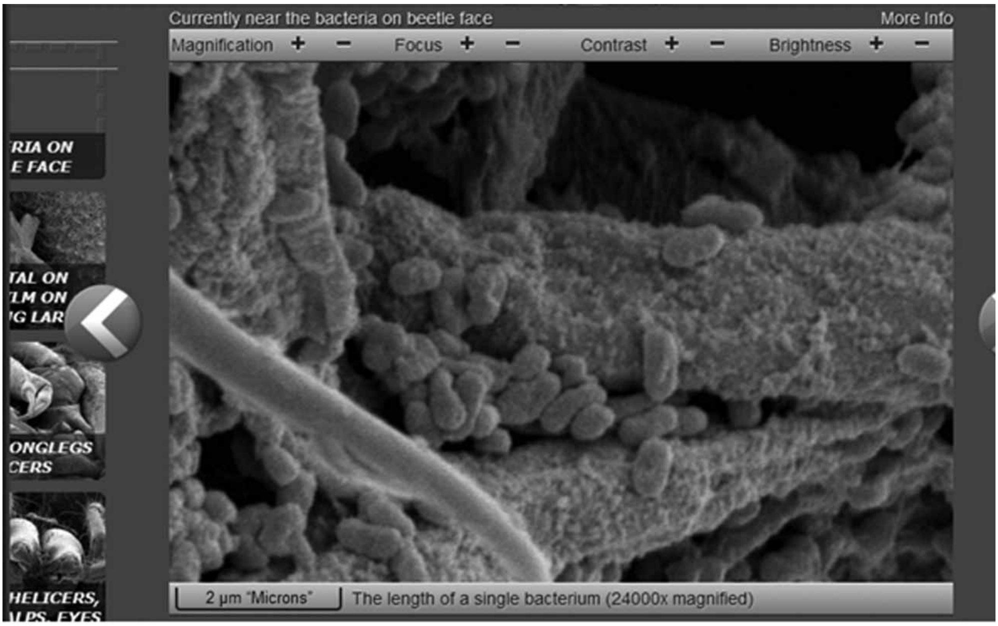

Figure 3. Screenshot of the upper portion of the *Remote Microscopy Lab* user interface if the student(s) have control of the scanning electron microscope

arrow located on the periphery of the webpage allowed students to maneuver between webpages within the user interface *Remote Microscopy Lab* module.

As shown in Figure 3, once students are granted control by the *Remote Microscopy Lab* scientists, a set of user controls appeared above the insect image. Students were able to change the magnification, focus, contrast, and brightness of the insect images. Control of the scanning electron microscope was granted by the scientists to each group.

Figure 4 shows the user interface that displays insects that students can view. The student moves his or her mouse cursor over the insect of choice, left clicks with the mouse, and the insect appears on the main page for the students to view. The insect images were pre-uploaded by the *Remote Microscopy Lab* scientists before the remote learning session was initiated with the students.

Each student in the experimental and control groups was given the opportunity to investigate a specimen by changing the magnification, or 'driving' the electron microscope to view different parts of the specimen.

Assessments. These assessments were given after the students completed the remote investigations.

1. The **Virtual Presence Survey** was modified from the Condition of Presence Survey developed by Witmer and Singer (1998). The survey items were modified to specifically address presence factors during a *Remote Microscopy Lab* investigation. The survey contained questions designed to elicit participants' perceived presence

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Figure 4. Screenshot of the user interface section that allowed students to choose an insect to view

during the remote access investigation by recording participants' perception of the four presence constructs: sensory, distraction, realism, and control. 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 0.87 for the modified presence survey. Values higher than 0.70 are often considered acceptable reliability (McDonald, 1999).

2. The **Student Interview Protocol** included 10 open-ended questions that were designed to document participants' sense of presence during a remote investigation and ownership. Examples of the questions included:

1. *How real was the remote session to you?*
2. *Did it feel that you were right beside the scientists during the session?*
3. *Did you lose track of time during the session?*
4. *Was it easy to use the webpage interface?*
5. *Did anything distract you from fully participating in the program?*

3. The **Teacher Interview Protocol** was designed to capture teachers' perceptions of *realness* and the teachers' perception of students' experiences during the remote investigation. Examples of the questions included:

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1. *How real was the session to you?*
2. *How important was it for the students to be able to communicate with the scientists and use laboratory equipment during the remote investigation?*
3. *What are the benefits and constraints of a remote investigation for teaching science?*

Procedural Protocol. Participants in the control and experimental group were introduced the study and the *Remote Microscopy Lab* program 4 weeks prior to the remote learning session. All overview sessions and remote learning sessions were facilitated by the same instructor throughout the study. The learning goals of the remote learning session focused on teaching students about insect morphology and anatomy as well as microscopy. Participants were given an overview of events and a description of the functions of an electron microscope.

Afterwards, the students in the experimental group were divided into groups of three students. Each group was given lab supplies (i.e. goggles, tweezers, magnifying glasses, vial of ethanol, and white paper) and was instructed to place *Drosophila* specimens on a white sheet of paper to select the best specimen for their group using a magnifying glass. After the groups selected their specimen, the *Drosophila* was carefully transferred with tweezers to a glass vial of ethanol. 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 prepare the insects for the remote investigation.

Students completed the *Remote Microscopy Lab* sessions using an Internet connection and computer. During the first 45-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 student-selected image of the *Drosophila* specimens in groups of three. The instructor located in the computer lab helped guide the students throughout their investigation.

Participants were able to ask the researchers operating the scanning electron microscope questions about microscopy and insects during the laboratory experience in real-time. In addition, each participant in both the control and experimental groups was allowed to control and manipulate the scanning electron microscope while viewing the specimens' antennae, mouthparts, exoskeleton, and wings. Students in the class were able to view their insect as well as the insects of each group as they were imaged with the scanning electron microscope.

During the second 45-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 using 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. The students in the experimental and control groups were aware that the scientists were there to address questions about insects and microscopy. In addition, each group in both the control and experimental groups were allowed to control the scanning electron microscope to view the specimen

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on the screen. The scientists were trained microscopists who voluntarily work with school groups on an ongoing basis.

Following the *Remote Microscopy Lab* program, the students completed the presence survey. Five control students and five experimental students were randomly chosen to participate in individual post-interviews.

Analyses

Presence Survey. Student responses to the *Presence Survey* were recorded [Likert items on a scale from 1 to 6 (1 strongly disagree to 6 strongly agree)] and analyzed by item and constructs. The presence constructs: *control* (eight items), *sensory* (four items), *distraction* (ten items), and *realism* (three items). The students' *Presence Survey* construct scores were compared across the treatment groups using the Mann–Whitney U test (two-tailed, alpha = 0.05) to determine if the experimental group experienced different perceptions of virtual presence than the control group. Furthermore, *Presence Survey* items were compared across treatment groups using the Mann–Whitney U test (two-tailed, alpha = 0.05). The Mann–Whitney U test evaluates the difference between two groups' (e.g. control and experimental group) ordinal data. All data are combined and then ranked in order to obtain the Mann–Whitney U score, which is then compared between the two groups to determine if the two groups have the same distribution.

Teacher and Student Interviews. Interviews were audio recorded, transcribed, and responses were examined by item. Frequencies of responses were noted and categories of responses were developed (specifically as they related to ownership, affect, realism, control, distraction, and sensory information).

Limitations

Care should be taken before generalizing the results 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, because this study presented students worked in groups, the influence of peers may have had a factor in student experience during the remote learning investigation. Further research may be needed to explore individual student experiences in a group during a remote investigation.

Results

In the sections that follow, the quantitative results for the survey are separated by the four constructs (control, sensory, realism, and distraction) and are followed by the results of the qualitative results of the interview.

Presence Survey: Overall results

Presence Survey Constructs. The results of the Mann–Whitney U test showed there were no significant differences in the overall presence scores of the students in the control and treatment groups (Table 1).

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Table 1. 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 Construct: Control

Presence Control Items. There were significant differences in student responses to specific items related to control. Students in the control group were more likely to report they felt in control of the computer program than students in the experimental group (Table 2).

When asked if students could easily chat with scientists through the chat box (item 8), the students in the control group were more likely to report they are able to chat easily with scientists.

Teacher and Student Interviews

Control and Interaction with Scientists. The interviews with the students revealed that they reported being able to manipulate the controls easily, and they felt they made a

Table 2. 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 *Remote Microscopy Lab* session.	38.22	35.78	622.00	0.761
2	The *Remote Microscopy Lab* computer program would respond to my directions.	41.25	31.75	477.00	0.046*
3	I enjoyed controlling the *Remote Microscopy Lab* session.	34.36	38.64	571.00	0.365
4	I was able to move around in the *Remote Microscopy Lab* session with ease.	33.07	39.93	524.00	0.153
5	My interactions with the *Remote Microscopy Lab* program were natural and easy.	32.26	40.74	495.50	0.078
6	I can easily manipulate the *Remote 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 *Remote Microscopy Lab* program.	35.28	37.72	604.00	0.609
8	I was able to chat easily with the *Remote Microscopy Lab* scientists through the chat window.	42.00	31.00	450.00	0.017*

Note: *p-value less than 0.05.

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connection with the scientists because they were able to ask questions and receive quick responses. The students thought the scientists were very personable and likeable.

All the teachers reported finding the remote microscopy session valuable. The teachers stated that it is extremely important for all the students to be able to communicate with scientists. 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'.

Presence Construct: Sensory

Presence Sensory Items. There were no significant differences between the control group and the experimental group for reported sensory factors. Students in both groups reported feeling engaged with their sight, hearing, and touch during the remote investigation Table 3.

Presence Construct: Distraction

Presence Distraction Items. 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 (Table 4). In contrast, the experimental group students were significantly more likely to report being able to easily concentrate and not being confused during interactions with the scientists.

Table 3. 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 *Remote Microscopy Lab* session.	33.99	39.01	557.50	0.288
2	My sense of hearing was highly engaged when participating in the *Remote Microscopy Lab* session.	38.67	34.33	570.00	0.362
3	My sense of touch was highly engaged when participating in the *Remote Microscopy Lab* session.	33.75	39.25	549.00	0.240
4	All my senses were highly engaged when participating in the *Remote Microscopy Lab* session.	36.39	36.61	644.00	0.962

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Table 4. 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 *Remote 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 *Remote 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 *Remote Microscopy Lab* session, I was aware of other sounds around me.	52.47	20.53	73.00	0.000*
4	When participating in the *Remote Microscopy Lab* session, I was aware of the *Remote Microscopy Lab* scientists.	36.31	36.7	641.00	0.936
5	When participating in the *Remote 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 *Remote Microscopy Lab* program.	36.31	36.69	641.00	0.935
7	The *Remote Microscopy Lab* scientists distracted me when I was using the *Remote Microscopy Lab* program.	35.43	37.57	609.50	0.648
8	The *Remote Microscopy Lab* program distracted me from learning.	34.33	38.67	570.00	0.363
9	I can concentrate easily while participating in the *Remote Microscopy Lab* session.	23.68	49.32	186.50	0.000*
10	The *Remote Microscopy Lab* scientists did not confuse me during the learning session.	23.24	49.76	170.50	0.000*

Note: *p-value less than 0.05.

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Presence Construct: Realism

Presence Realism Items. Students in the control and in the experimental group reported similar levels of perceived realism factors (Table 5).

Teacher and Student Interviews: Perceptions of realness. When asked in an interview about the *realness* of the experience, there were differences in the perceptions of students and teachers. The teachers regarded the *realness* of the *Remote 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

Table 5. 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 *Remote Microscopy Lab* program with ease.	26.61	26.25	284.00	0.935
2	I lost track of time when participating in the *Remote Microscopy Lab* session.	27.13	25.09	265.50	0.636
3	I quickly adjusted to using the *Remote Microscopy Lab* program.	26.94	25.50	272.00	0.733

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students to use a scanning electron microscope and communicate with scientists, the *realness* of the experience was reduced because the students, the microscope, and scientists were not located in the same location.

In contrast to the teachers, all of the students interviewed stated that the experiences were *very real* with the exception of one student from the experimental group that stated it was not real because he was not actually using a scanning electron microscope in a laboratory, which is a similar notion reported by teachers. Student (C3) 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 (E4) 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'. Additional student remarks are listed below:

> ' … it was like … I was there! I was doing this myself!' (Student C1)
>
> 'Very real, even though it was on the computer, it was real. We were doing it ourselves.' (Student C2)
>
> 'It was like I was actually looking into a microscope!' (Student E2).

In addition, most students reported losing track of time during the sessions. One student (C1) 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 (C3) declared that he ' … didn't want to leave,' while student (E1) lost track of time because ' … I was so interested in what was going on'.

Discussion

As new technologies are developed for remote and virtual investigations, teachers want to know if these experiences represent realistic science experiences. Here, virtual presence included four constructs: control, sensory, distractions, and realism. The study was designed to allow us to see whether students who selected their own insect to investigate would find the experience more realistic. However, students' reported perceptions of presence were not significantly different across treatment groups. However, there were items that were different for the control and experimental groups.

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The differences in the control and experimental groups for distractions suggest that students in the experimental group were more engaged or immersed in the experience (less distracted). The results may suggest that students in the experimental group that had the opportunity to choose their own insect were less distracted 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 insect investigated during the remote program.

Relating ownership to perceived virtual presence, the control group students thought the program was interesting, but it was more of a *fun project*. 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*, they asked *different questions of the scientists*, and spoke about how they want *to know more about their insect*. Student (E2) 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'. However, further research on *ownership* is needed to document the level of students' engagement and interest in the remote investigations.

Realness of Remote Investigations

The *realness* of the remote investigation is a construct of virtual presence that describes the participants' perception 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. 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, 'I 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. As seen in the results of the student interviews, both control and experimental students perceived the remote investigation as *real*.

The divide between students' and teachers' perception of *realness* in this remote investigation may be due to the differences 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. It is also possible that the students (who have grown up using technology daily) may have found the path from idea to manipulation to be more seamless than the teachers. These results support the use of remote microscopy as a tool for students' science investigations. The perceived *virtual presence* constructs during the investigation suggest that students were immersed in the experience. With the increase in costs associated with science laboratory equipment, the use of remote investigations allows students to learn with these sophisticated tools without having to travel to a university location.

The results found here for *ownership* of the specimen being imaged (although preliminary) suggest that having choice of an insect may affect the engagement of students in the investigation. The combination of choice, ownership, and virtual presence may emerge as important factors that help make remote investigations realistic and effective in promoting learning. Future research is needed to further document how control and choice influence learning science in investigations. We need to know more about when virtual and remote experiences become more or less real or present for students. Furthermore, although the real-time contact with scientists was valued by students and teachers, having live interactions with scientists is expensive and limits the number of schools that can remotely experience tools such as a scanning electron microscope. Further research is needed to study how other variables, such as time of day, teacher experience (both classroom and science laboratories), student choice of variables, selection of equipment, and influence of the teacher and other students on students' experiences that take place during a remote learning investigation. Additionally, it is not clear from this study why students and teachers had different perceptions of what is considered real in a remote learning investigation as well as the control group reporting to be more distracted with a higher level of perceived control than the experimental group. As a result, research is needed to examine why these differences emerged. As intelligent tutoring and technology to support virtual scientists evolves, we need research to inform scientists and teachers about which aspects of student–scientists communications are essential for learning and engagement. Clearly, opportunities are opening for students in remote and low wealth areas to have high-quality science investigations remotely with state-of-the-art science tools. Understanding what works for learning science and why remains as an important research endeavor.

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Acknowledgements

The authors would like to thank Bugscope (bugscope.beckman.illinois.edu) and Scott J. Robinson (Beckman Institute for Advanced Science and Technology, University of Illinois at Urbana-Champaign) for their many suggestions and support for this research.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

Bystrom, K., & Barfield, W. (1999). Collaborative task performance for learning using a virtual environment. *Presence: Teleoperators and Virtual Environments*, *8*(4), 435–448.

Catlin-Groves, C. (2012). The citizen science landscape: From volunteers to citizen sensors and beyond. *International Journal of Zoology*, *2012*, 1–14.

Childers, G. (2014). *Ownership of data: Students' investigations with remote electron microscopy*. (Doctoral dissertation). North Carolina State University, Raleigh, NC.

Childers, G., & Jones, M. G. (2014). Students as virtual scientists: A review of remote microscopy use in education. In A. Mendez-Vilas (Ed.), *Microscopy: advances in scientific research and education* (pp. 1195–1198). Spain: Formatex Research Center.

Chinn, C. A., & Hmelo-Silver, C. E. (2002). Authentic inquiry: Introduction to the special section. *Science Education*, *86*(2), 171–174.

Chinn, C. A., & Malhotra, B. A. (2002). Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks. *Science Education*, *86*(2), 175–218.

Corter, J., Esche, S., Chassapis, C., Ma, J., & Nickerson, J. (2011). Process and learning outcomes from remotely-operated, simulated, and hands-on student laboratories. *Computers and Education*, *57*(3), 2054–2067.

Hanauer, D., Frederick, F., Fotinakes, B., & Strobel, S. (2012). Linguistic analysis of project ownership for undergraduate research experiences. *CBE Life Sciences Education*, *11*(4), 378–385.

Hedley, N., Billinghurst, M., Postner, L., May, R., & Kato, H. (2002). Explorations in the use of augmented reality for geographic visualization. *Presence: Teleoperators & Virtual Environments*, *11*(2), 119–133.

Jones, M., Andre, T., Kubasko, D., Bokinsky, A., Tretter, R., Negishi, A., … Superfine, R. (2004). Remote atomic force microscopy of microscopic organisms: Technological innovations for hands-on science with middle and high school students. *Science Education*, *88*(1), 55–71.

Jones, M., Andre, T., Superfine, R., & Taylor, R. (2003). Learning at the nanoscale: The impact of microscopy on concepts of viruses, scale, and microscopy. *Journal of Research in Science Teaching*, *40*(3), 303–322.

Ku, H., Ahfock, T., & Yusaf, T. (2011). Remote access laboratories in Australia and Europe. *European Journal of Engineering Education*, *36*(3), 253–268.

Lee, K. (2004). Presence, explicated. *Communication Theory*, *14*(1), 27–50.

Lombard, M., & Ditton, T. (1997). At the heart of it all: The concept of presence. *Journal of Computer-Mediated Communication*, *3*(2), online journal. doi:10.1111/j.1083-6101.1997.tb00072.x

Lowe, D., Newcombe, P., & Strumpers, B. (2013). Evaluation of the use of remote laboratories for secondary school science education. *Research in Science Education*, *43*(3), 1197–1219.

Ma, J., & Nickerson, J. (2006). Hands-on, simulated, and remote laboratories: A comparative literature review. *AMC Computing Surveys*, *38*(3), 1–24.

McDonald, R. P. (1999). *Test theory: A unified treatment*. Mahwah, NJ: Erlbaum.

Mikropoulos, T. (2006). Presence: A unique characteristic in educational virtual environments. *Virtual Reality*, *10*, 197–206.

O'Day, D. (2007). The value of animations in biology teaching: A study of long-term memory retention. *CBE Life-Sciences Education*, *6*, 217–223.

O'Neill, T. (2010). Fostering spaces of student ownership in middle school science. *Equity & Excellence in Education*, *43*(1), 6–20.

O'Neill, T., & Barton, A. (2005). Uncovering student ownership in science learning: The making of a student created mini-documentary. *School Science and Mathematics*, *105*(6), 292–301.

Schifter, C., Ketelhut, D., & Nelson, B. (2012). Presence and middle school students' participating in a virtual game environment to assess science inquiry. *Educational Technology & Society*, *15*(1), 53–63.

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Scoresby, J., & Shelton, B. (2011). Visual perspectives within educational computer games: Effects on presence and flow within virtual immersive learning environments. *Instructional Science*, *39* (3), 227–254.

Sheridan, T. (1992). Musings on telepresence and virtual presence. *Presence*, *1*, 120–126.

Silvernagel, C., Schultz, R., Moser, S., & Aune, M. (2009). Student-generated intellectual property: Perceptions of ownership by faculty and students. *Journal of Entrepreneurship Education*, *12*, 13–33.

Slater, M., & Usoh, M. (1993, September 18). *Presence in immersive virtual environments*. IEEE Virtual Reality Annual International Symposium, Seattle, WA, 90–96.

Steuer, J. (1992). Defining virtual reality: Dimensions of determining telepresence. *Journal of Communication*, *42*(4), 73–93.

Van Auken, H. (2013). Influence of a culture-based entrepreneurship program on student interest in business ownership. *International Entrepreneurship and Management Journal*, *9*(2), 261–272.

Walsh, J., Sun, J., & Riconscente, M. (2011). Online teaching tool simplifies faculty use of multimedia and improves student interest and knowledge in science. *CBE-Life Sciences Education*, *10*, 298–308.

Winn, W., Windschitl, M., Frauland, R., & Lee, Y. (2002, October 24). *When does immersion in a virtual environment help students construct understandings?* Paper presented at the International Conference on the Learning Sciences (ICLS), Seattle, WA.

Witmer, B., & Singer, M. (1998). Measuring presence in virtual environments: A presence questionnaire. *Presence: Teleoperators & Virtual Environments*, *7*(3), 225–240.

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