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INTERNATIONAL JOURNAL OF SCIENCE EDUCATION, 2017
VOL. 39, NO. 3, 257–273
http://dx.doi.org/10.1080/09500693.2016.1278483

Learning from a distance: high school students' perceptions of virtual presence, motivation, and science identity during a remote microscopy investigation

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ABSTRACT

Through partnerships with scientists, students can now conduct research in science laboratories from a distance through remote access technologies. The purpose of this study was to explore factors that contribute to a remote learning environment by documenting high school students' perceptions of science motivation, science identity, and virtual presence during a remote microscopy investigation. Exploratory factor analysis identified 3 factors accounting for 63% of the variance, which suggests 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 programme and being recognised as a science-oriented individual) were factors that contribute to a student's experience during a remote investigation. Motivation, science identity, and virtual presence in remote investigations are explored.

ARTICLE HISTORY
Received 11 June 2016
Accepted 30 December 2016

KEYWORDS
Motivation; learning technologies

Introduction

The advent of computer technologies has enabled students to investigate science in novel ways such as remotely accessing telescopes to explore astronomy or accessing scanning electron microscopes to learn about microscopy (Jones, Andre, Superfine, & Taylor, 2003; Jones, et al. 2004; Lubin & van der Veen, 1992). Remote access technology allows students to use scientific tools and communicate in real time with scientists anywhere in the world. The use of these new technologies in the classroom may have significant implications for student achievement, motivation to do science, and perceptions of science identity in a scientific setting.

Technology applications are being promoted as one way teachers can support student learning, motivation, and preparedness for the future (Argyriou, Sevaslidou, & Zafeiriou, 2010). Lowe, Newcombe, and Strumpers (2010) suggested that the engagement of students in science classroom laboratories is essential 'to [address] a shortfall of students entering

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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). However, due to students' waning interest in science classes, limited access and funding to maintain advanced equipment and technologies in science classes, and the inadequate preparation of K-12 science teachers to support learning through the use of technology, students perceive science as being rigorous and not interesting (Iskander, Kapila, & Kriftcher, 2010; Orsak, Munson, Weil, Conner, & Rummel, 2004). Now, because of advancements in technology and school access through the utilisation of computers and an Internet connection, remote access laboratories may help address the aforementioned issues by offering students and teachers the opportunity to connect with scientists and use advanced instrumentation with little to no cost to the school (Childers, 2014; Childers & Jones, 2014). Students' access to scientists and advanced equipment, such as a scanning electron microscope, could foster student interest in science and motivate students to pursue science-related careers.

The effectiveness of remote access laboratories for learning science has rarely been investigated (Lowe et al., 2010; Ma & Nickerson, 2006). 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 such as motivation or student identity (Lowe et al., 2010; Ma & Nickerson, 2006). Ma and Nickerson (2006) noted that engineering remote laboratories are growing in popularity at the university level because they allow 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 within remote learning environments (Lowe et al., 2010).

This study aims to address a gap that exists in research about the relationships among students' science motivation, science identity, and perception of virtual presence in a remote learning environment. The present study addresses this research question as follows:

> Research question: What are the underlying factors of students' motivation, science identity, and perception of presence during a remote learning investigation?

Literature review

Remote technologies

Remote technologies allow students and teachers to have access to the tools and laboratory equipment (e.g. scanning electron microscope) and to communicate with scientists through an Internet connection (Childers & Jones, 2014; Lowe et al., 2010; Ma & Nickerson, 2006). Students are able to develop experiments and engage in scientific inquiry (e.g. observing, questioning, collecting and analysing data, and interpreting results) (Lowe et al., 2010), often alongside of scientists during a remote investigation. Research investigating remote learning environments has shown to increase student interest in science and overall academic achievement (Walsh, Sun, & Riconscente, 2011).

In general, laboratories have been shown to be essential tools for learning science, as they offer real science experiences (Boud, Dunn, & Hegarty-Hazel, 1986; Hofstein &

Lunetta, 1982). Currently, many laboratories have been transformed into computerised and simulated experiences, effectively changing how laboratory work is implemented in science courses (Scanlon, Morris, Paolo, & Cooper, 2002). However, debates have emerged 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, and Nickerson (2011), there are mixed, complex results in interpreting the benefits of face-to-face, simulated, and remotely operated laboratories, suggesting 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). The researchers reported that students were 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 have focused on student learning and professional skills when compared to hands-on laboratories and simulations that emphasise design and professional skills (Ma & Nickerson, 2006).

Although research in remote learning environments has been limited in scope and depth, there are a few studies that have investigated learning and student experiences in conjunction with remote access technology utilisation in classrooms. Childers and Jones (2015) studied 72 high school students' perceptions of virtual presence (how *real* is remote learning environment) and ownership during a remote electron microscopy investigation involving the study of insects. Students who had the choice of selecting their insect reported being more *present* than the students who did not have the opportunity to select their own insect for the remote microscopy investigation. Additionally, students generally indicated the sessions as being *more real* than teachers during the remote microscopy investigation. Furthermore, Lowe et al. (2010) 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.

Additionally, two related studies (Jones et al., 2003, 2004) investigated high school and middle school students' understanding of viruses using a remote atomic force microscope along with haptic tools (a device that enables a user to sense force feedback of an environment in a simulated computer program). The studies showed that there were significant gains from pre- to post instruction for students for attitudes, knowledge of viruses, development of conceptual models, and understanding of scale. While the focus was on the haptic feedback devices, the researchers suggested that experiences with technology may be beneficial to students' engagement, motivation, and learning of science concepts.

There is a need to study the efficacy of remote learning environments with K-12 students to understand how utilising remote technologies in the classroom influences student engagement and interest in science as well as how the technology can be incorporated into learning experiences (Childers & Jones, 2015). Understanding how students interact with remote learning environments is needed to support educators in designing effective remote access technology educational programmes. There are many factors that may contribute to the successful implementation of a remote learning environment including students' perceived level of *virtual presence* (how *real* is the remote learning environment), students'*motivation* to do science, and how students identify with the remote investigation (students'*science identity*).

Virtual presence

Presence is an individual's perception of the *realness of* a virtual environment. There are several definitions of presence that span varied disciplines (e.g. psychology, computer science, and engineering) and can be partitioned into other related areas (physical, telepresence, and virtual) to describe an individual's experience (Lee, 2004; Lombard & Ditton, 1997; Ma & Nickerson, 2006; Sheridan, 1992). For the purpose of this study, *virtual presence* is the emphasis because remote learning environments are mediated by Internet and network connections.

Many researchers have attempted to define the factors that contribute to presence. Sheridan (1992) defined presence as an individual's ability to feel physically present at a remote site. Feeling *present* can be contributed through the engagement of the senses, control of the environment, and manipulability of the remote technology programme. Presence has also been defined as the general sense of being *present* through a communicative medium (Steuer, 1992). Lombard and Ditton (1997) stated that presence is how *vivid*, *interactive,* and *engaging* the communication medium is with the individuals. Additionally, presence is described as being a compilation of several factors (realism, transportation, immersion, social actor, medium, and social richness) for there to be a high sense *realness* which may alter individuals' perception of reality.

The framework of presence that will be the focus in this study is Witmer and Singer's Conditions of Presence. This model depicts the level of involvement, distraction, and immersion in a virtual environment (Schifter, Ketelhut, & Nelson, 2012; Witmer & Singer, 1998). These conditions for presence are influenced by four factors that govern participants' attention in a virtual reality context:

1. *Distractions* may originate from the external or internal environment of the remote system, such as interruptions from other individuals or interface technological problems.
2. *Sensory information* is generated output of information (e.g. auditory, visual, and tactile) processed by the individual in a remote system.
3. *Control factors* may be perceived by individuals as the ability to choose, access, and navigate the technology's interface efficiently.
4. *Perception of realism* is the extent to which individuals feel how *real* the experience is by defining it as if the individuals believed they were located in the research lab instead of the classroom.

In this study, the remote learning environment consists of students' access to scientists (via an online chat module shown in Figure 2) and the laboratory technology (e.g. scanning electron microscope) used to promote learning.

Research on the relationships between presence, student learning, and performance of tasks suggests that higher levels of perceived presence positively influence students' performance and learning objectives (Bystrom & Barfield, 1999; Hedley, Billinghurst, Postner, May, & Kato, 2002; Mikropoulou, 2006; Sheridan, 1992; Slater & Usoh, 1993;

Steuer, 1992; Winn, Windschitl, Frauland & Lee, 2002). However, the link between presence and learning has been questioned by other researchers. Some researchers argue that participants with a high level of perceived presence are already highly engaged within the learning environment (Scoresby & Shelton, 2011). Furthermore, Childers and Jones (2015) investigated high school students' perceived realness of a remote investigation in which some students indicated that their interactions with the scientists made the experience feel real. As a result of this access, students' perceptions of how *real* a remote investigation may contribute to their motivation and perception of identity during a science learning lesson using laboratory equipment while communicating with scientists in real time. Understanding the underlying constructs among motivation, presence, and students' identity while conducting remote investigations can provide insight into how to best structure remote access investigations for students.

Motivation

To fully understand student interactions, interests, and learning during a remote investigation, it is important to determine if remote learning environments are motivating to learners. Motivation is defined as an inner behavioural drive that enables individuals to achieve goals. The concept of motivation often defines behaviours as being intrinsic or extrinsic in nature. Intrinsic motivation describes individuals engaging in behaviours for their own personal interest and self-satisfaction, whereas individuals who are motivated by outside extrinsic factors, behaviour is based on a separable outcome, such as rewards (Deci & Ryan, 1985; Deci, Vallerand, Pelletier, & Ryan, 1991; Eccles, Simpkins, & Davis-Kean, 2006).

Self-determination theory (SDT) distinguishes between motivation behaviours by defining them as either self-determined (behaviours are endorsed by choice) or controlled (behaviours are controlled through compliance) (Deci & Ryan, 1991; Deci et al., 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 behaviours can be self-determined through the process of internalisation (Deci & Ryan, 1985; Deci et al., 1991). Internalisation is the process of regulating and converting non-intrinsically motivated behaviours into inner motivation (Deci, Eghrari, Patrick, & Leone, 1994; Deci et al., 1991; Schafer, 1968). Internalising motivation behaviours coupled with intrinsic motivation may promote student interest in learning (Deci et al., 1991).

SDT suggests that individuals have psychological innate needs to function and promote growth (Deci et al., 1991). The authors state that these psychological needs emphasise 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 his or her 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 (Black & Deci, 2000; Deci et al., 1991; Hanrahan, 1998; Lavigne & Miquelon, 2007; Williams, Wiener, Markakis, Reeve, & Deci, 1994). Recently, it has been proposed that educational games and other various software learning systems increase student interest and motivation (Argyriou et al., 2010; Ford, Wyeth, & Johnson, 2012; Ting, 2010). However, there is little research on the connection between motivation and remote learning environments. As noted above, remote access technology enables students to utilise research-grade science tools and communicate with scientists. As a result, there are significant implications of SDT in remote learning environments for students' feelings of autonomy, their sense of competence, and the students' ability to relate the scientists (Childers, 2014).

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, because it is argued that science is a social construct manifested by human activity, student science identity is moulded 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 et al., 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 et al., 2010, p. 565). For example, does conducting technical research alongside of scientists who are located at a distance from the school promote students' perceptions of themselves as scientists or does doing investigations with sophisticated equipment promote science identity?

For this study, Carlone and Johnson's (2007) science identity framework is 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*: an individual's ability to implement various scientific practices.
2. *Recognition:* the extent to which an individual is recognised (by themselves or others) as being a *science person*.
3. *Competence:* an individual'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 who would otherwise be unavailable. Remote learning may have unique implications on students forming science identities in classroom settings (Childers, 2014).

Proposed factors in a remote learning environment

The frameworks reviewed thus far (virtual presence, SDT, and science identity) are proposed for examining remote learning environments (Figure 1). SDT and the construct of science identity share similar characteristics that define how participants identify with science and are motivated to do science. Students' perception of motivation to do science ultimately shapes 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 endeavours. 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 *recognise* the students' scientific ability and aptitude, promoting continued interest in learning science. Remote learning environments can enable students to establish a connection with scientists which may advance students' interest and motivation in science and influence their identity (Childers, 2014; Childers & Jones, 2015).

Depending on the structure of the science instruction and the classroom setting, teachers can have either 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 learn in remote environments and can originate from different sources often in the student's immediate environment in the classroom (this does not include the remote learning environment), such as inappropriate peer interactions during a remote investigation or an interruption of the classroom setting (e.g. 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

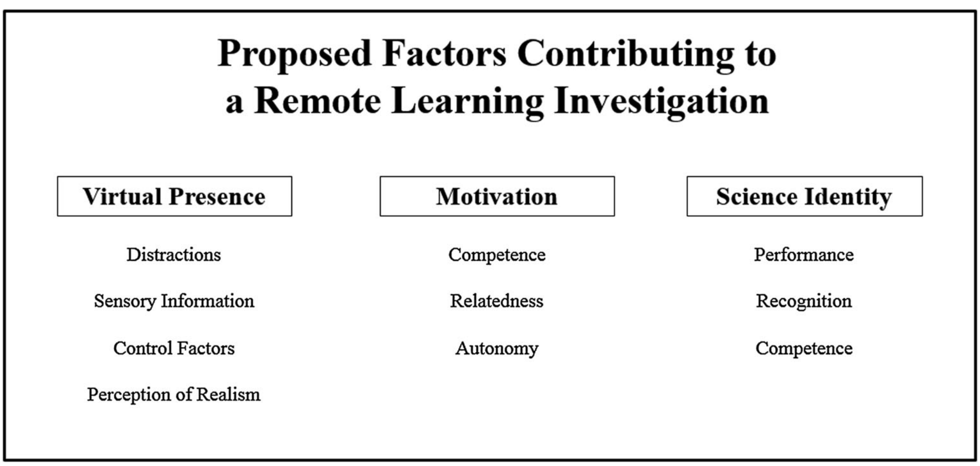

Figure 1. Proposed factors contributing to a remote learning investigation.

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). Although we have documented learning and motivation in traditional classroom settings, the unique affordances of remote learning with scientists' laboratories and equipment from a distance raise questions about how remote learning can best be used to promote learning (Childers, 2014; Childers & Jones, 2015).

Methods

The study is part of a series of studies investigating remote electron microscopy technologies which was conducted at an urban high school in the southeastern United States (Childers, 2014; Childers & Jones, 2015). This research question was addressed as follows:

> Research question: What are the underlying factors of students' motivation, science identity, and perception of presence during a remote learning investigation?

Participants

The high school has approximately 200 students enrolled in grades 9 through 12 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 comprised 29 males (41%) and 43 females (59%). The ethnic composition of the students in the study consisted of 1.4% American Indians, 2.8% Asians, 73.2% African-Americans, 11.3% Caucasians, 1.4% Hispanics, and 9.9% identified as *other*. Additionally, students reported in a previous, related study that before participating in the *Remote Microscopy Lab* investigation, students' interactions with insects were limited (26% of students collected insects) but learning about insects through TV programmes was much higher (68%) (Childers, 2014).

Instructional technology

This study builds on a previous study investigating students' perceptions of presence during a remote microscopy investigation (Childers & Jones, 2015). *Remote Microscopy Lab* (a pseudonym) is a remote electron microscopy programme hosted by a university located in the Midwest of the United States. Participants have the option of collecting and sending insects through the mail to the *Remote Microscopy Lab* or using the insects that are available to the scientists in the lab. The insects are mounted on a stage by the scientists, and participants interact with the web-based *Remote Microscopy Lab* programme to view the insect specimens, change the focus and magnification, and communicate with the scientists in real time through an online interactive chat module (shown in Figure 2).

Procedural protocol

Students were introduced to the study and the *Remote Microscopy Lab* programme one month prior to the instruction and participation in two remote learning sessions. All instructional and remote sessions were assisted by the same facilitator who was a former science teacher and part of the research team. The facilitator was present with the students in the computer laboratory room for instructional purposes and technological assistance. The learning goals of the session concentrated on microscopy and insect anatomy (structure and function). The *Remote Microscopy Lab* investigation required a computer with a reliable Internet connection.

During each remote investigation, students in the study were given the opportunity to control the scanning electron microscope by selecting the insect 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 two remote investigation sessions (each session approximately 45 minutes in length), 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 by manipulating the settings in the remote environment and by asking the scientists (in real time) questions about microscopy and insects (see Figure 2 to view the chat screen between students and the scientists). The science teachers were present for each session; however, instruction and technology assistance were led by the same facilitator. After the two remote sessions were completed, the students completed post-surveys that documented their motivation to do science, science identity, and perception of virtual presence during the remote microscopy investigation (Childers, 2014; Childers & Jones, 2015).

Assessments

The post-surveys were selected to document students' perceptions of motivation, science identity, and perceived presence over the course of two remote access investigations with

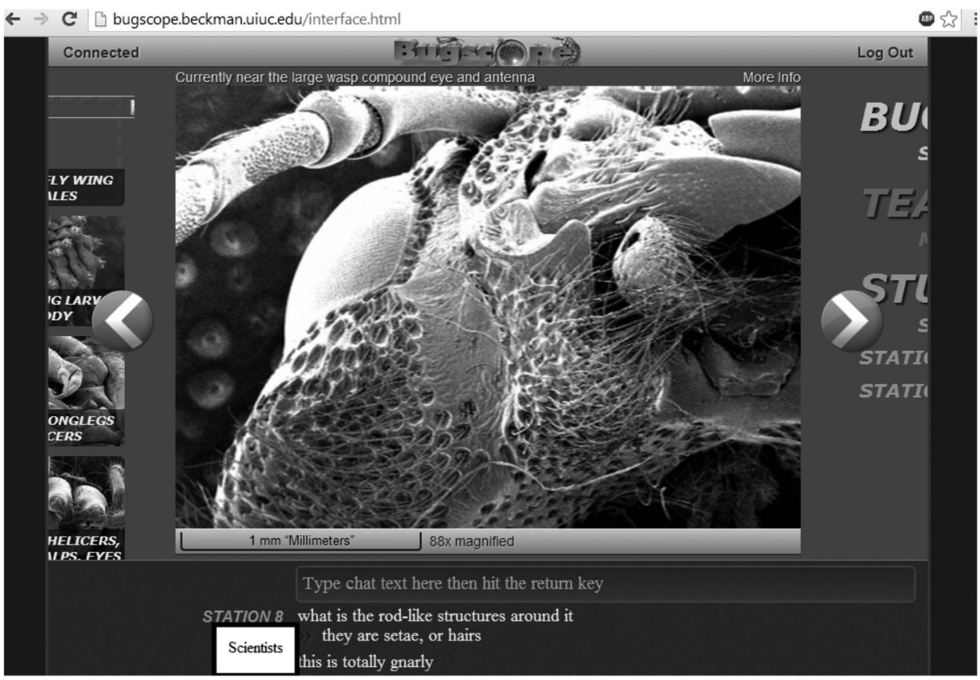

Figure 2. Screenshot of the main *Remote Microscopy Lab* interactive session screen.

Table 1. Examples of assessment items on surveys that relate to constructs of virtual presence, motivation, and science identity.

Construct	Survey item
Presence	
a. Sensory factor	'My sense of sight was highly engaged when participating in *Remote Microscopy Lab* session.'
	'My sense of touch was highly engaged with participating in *Remote Microscopy Lab* session.'
b. Distraction factor	'When participating in *Remote Microscopy Lab* session, I was aware of other events occurring around me.'
	'I can concentrate easily while participating in *Remote Microscopy Lab* session.'
c. Realism factor	'I lost track of time when participating in *Remote Microscopy Lab* session.'
	'I was easily distracted when participating in *Remote Microscopy Lab* session.'
d. Control factor	'I was able to move around in *Remote Microscopy Lab* session with ease.'
	'I can easily manipulate *Remote Microscopy Lab* session in any way I want.'
Motivation	
a. Intrinsic motivation	'Learning about science with the *Remote Microscopy Lab* is interesting.'
	'Learning science with the *Remote Microscopy Lab* makes my life more meaningful.'
b. Autonomy	'I feel obligated to with the *Remote Microscopy Lab* project.'
	'I have a choice in choosing what I want to learn during the *Remote Microscopy Lab* session.'
c. Competence	'I use strategies to learn science well during the *Remote Microscopy Lab* session.'
	'I study hard to learn science.'
d. Relatedness	'I feel I am able to interact freely with the scientists during the *Remote Microscopy Lab* session.'
	'The scientists encouraged me to explore the activities in *Remote Microscopy Lab* session.'
Science identity	
a. Performance	'I think I did well in during the *Remote Microscopy Lab* session.'
	'I could easily use the *Remote Microscopy Lab* tools to view the insect.'
b. Competence	'I feel confident that I can learn a lot about insects while using the *Remote Microscopy Lab* program.'
	'I can do advanced work in science by using the *Remote Microscopy Lab*.'
c. Relatedness	'It is important to me that others see me as a scientist.'
	'I can relate to the *Remote Microscopy Lab* scientists.'

Note: Please see the authors' research for full access to original questionnaire items.

the *Remote Microscopy Lab*. Examples of questions pertaining to the identified constructs and factors of the hypothesised remote learning environment are shown in Table 1. The assessments included the following:

1. The *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 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 the completion of a remote access investigation. Student responses to the Likert items were on a 6-point scale (strongly disagree to strongly agree). Cronbach's alpha was calculated with a reliability value of 0.87. Values higher than 0.70 are often considered acceptable reliability (McDonald, 1999).
2. The *Motivation Survey* was adapted from Glynn's (Glynn, Brickman, Armstrong, & Taasoobshirazi, 2011) 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 during a remote access investigation. Self-determination factors included within the survey questions were competence, relatedness, and autonomy. Student responses to the Likert items were on a 6-point

scale (strongly disagree to strongly agree). Cronbach's alpha was calculated with a reliability value of 0.90.

3. The *Science Identity Survey* was an adaptation of the Maximizing the Impact of STEM Outreach survey (Wiebe, Faber, Corn, Collins, & Unfried, 2013) that documented students' perceptions of interest and motivation to do science. An item to capture students' interest in insects was added to the survey. Student responses to the Likert items were on a 6-point scale (strongly disagree to strongly agree). Cronbach's alpha was calculated with a reliability value of 0.89.

Analyses

Survey analysis. The student responses to the *Presence, Motivation, and Science Identity* surveys were recorded (Likert items on a 6-point scale from strongly disagree to strongly agree) and reviewed by factor and construct. The mean and standard deviation for each construct were calculated. The factors for each survey construct are listed below:

Presence Survey: control, sensory, distraction, and realism

Motivation Survey*: intrinsic motivation, career interest, competence, relatedness, and autonomy*

Science Identity Survey: *performance, recognition, competence, science interest*

Exploratory factor analysis: Because there were several variables identified (e.g. motivation, presence, science identity) and the unknown prior experiences during a remote investigation, an exploratory factor analysis was used to identify the factors within the established variables that contributed to the perception of remote investigations. Thirteen identified variables relating to remote investigations were factor analysed using the principal component analysis of extraction utilising the Varimax rotating method.

Results

In the sections that follow, the descriptive statistics are presented for the identified factors for *Presence, Motivation, and Science Identity* followed by the results of the exploratory factor analysis.

Survey descriptive statistics

The calculated descriptive statistics (mean and standard deviation) for the identified factors of *Presence, Motivation, and Science Identity* are shown in Table 2.

Exploratory factor analysis

The exploratory factor analysis revealed the core variables that contribute to students' motivation to do science, science identity, and virtual presence during remote investigations. Assumption checks for the 13 variables were established. Inter-correlations between factors generally exceeded 0.30 with many correlations over 0.50 for each

Table 2. Mean and standard deviation of the factors for presence, motivation, and science identity constructs.

Construct	Mean	Standard deviation
Presence – Control	4.58	0.87
Presence – Sensory	4.76	1.05
Presence – Distraction	3.67	0.44
Presence – Realism	4.75	1.08
Motivation – Intrinsic motivation	4.23	0.71
Motivation – Competence	4.37	0.78
Motivation – Relatedness	4.93	1.02
Motivation – Autonomy	4.23	0.65
Motivation – Career interest	4.30	1.34
Science Identity – Performance	4.29	0.81
Science Identity – Recognition	3.02	1.31
Science Identity – Competence	4.47	0.89
Science Identity – Science interest	3.17	1.12

factor set. Correlations exceeding 0.30 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 et al., 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, 19741974; Kaiser & Rice, 1974). While the sample size was relatively small, 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 analysed with factor analysis using the principal component analysis of extraction utilising the Varimax rotating method. The exploratory factor analysis yielded three factors (eigenvalues over 1.000) accounting for 63.28% of the variance for all 13 variables. Factor 1 consisted of students' perceptions of science identity of *performance*'I can do it' and *competence*'I know it' along with *intrinsic motivation*. Factor 2 consisted 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 consisted of *realism*'how real is the remote environment to me' and science identity factor of *recognition*'they see I can do it'. Based on the results of the factor analysis, factors that contributed to a remote investigation are shown in Figure 3.

The first factor explained 27.04% of the variance and was labelled *Science Learning Drive* due to the high loading of science identity variables *performance*, *competence*, and *intrinsic motivation*. This factor 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 utilising 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 accounted for 21.56% of the total variance, was labelled *Environmental Presence* because of the 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

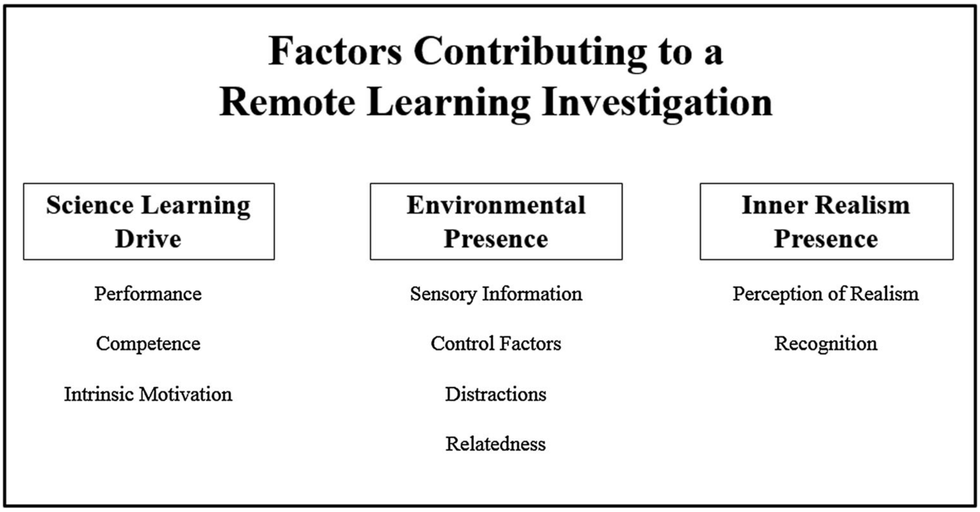

Figure 3. The factors, *Science Learning Drive*, *Environmental Presence*, and *Inner Realism Presence*, perceived by students within the remote learning environment.

variables in this factor are physically based within the students' proximate environment, which includes the student, computer, and remote technology programme. The students' awareness of their immediate surroundings 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 3, labelled *Inner Realism Presence*, accounted for 14.6% of the total variance. *Inner Realism Presence* contributed to the high loading of a presence variable, *realism*, and a 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 recognised as a science-oriented individual because the students were in control in a learning environment that was perceived as being *real*.

Limitations

Although the checks of assumption for the exploratory factor analysis were met, the results should be taken with caution due to the relatively small sample size. Additionally, the sample included a high proportion of under-represented and low socio-economic students. Further research may be needed to explore student experiences and factors that influence learning, interaction, and motivation during remote investigations with a larger sample and with different school contexts.

Discussion

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. As indicated by previous studies, motivation, science identity, and virtual presence were influential factors that were associated with student learning and interest in science during remote investigations and virtual simulations (Childers, 2014; Childers & Jones, 2015; Lowe et al., 2010; Ma & Nickerson, 2006; Walsh et al., 2011). 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 *Remote 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 who engaged in collecting insects during the *Remote Microscopy Lab* remote investigation may have altered how students perceive the relationship between themselves and the scientists. One interpretation of the results found here is that the students collecting data may have felt a closer association with the scientists and thus may report fewer distractions during the remote investigation.

The Inner Realism Presence construct was 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' interest in being recognised 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 as a result of being recognised as a science-oriented individual because the students may believe that their investigations mimic the actions of scientists.

There is a need for future studies to investigate other factors that contribute to successful remote investigation experiences for students, such as engagement, a revised view of *ownership of data* and how students' perceptions of *ownership of data* influence 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.

Additionally, more information is needed about the relationships between understanding students' prior experiences, interest, attitudes, and perceptions of objects investigated (such as insects), and students' interactions. 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. It is possible that scaling the learning environment 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, state tests, classroom structure, and partnering scientists/laboratories, may also affect how remote learning environments are utilised in the classroom. Furthermore, this study should be replicated with larger sample sizes to more fully document student learning in remote learning environments.

As there is an increased demand for a technologically literate workforce, it is imperative for teachers to prepare their students to interact with technologies to ensure the students to become science-oriented and technologically oriented citizens. Technology use in classrooms may support students' understanding of the interdependence of science, engineering, and technology disciplines. Because new advancements in technology that will affect how society interacts with the environment, teachers need to prepare students to be effective, science-educated individuals who are able to make evidence-based decisions related to science and technology. 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.

Acknowledgments

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.

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