ASSESSING THE IMPACT OF CITIZEN SCIENCE ON MOTIVATION, CIVIC AWARENESS, AND UNDERSTANDING OF THE SCIENTIFIC PROCESS IN A COLLEGE MICROBIOLOGY SYNCHRONOUS CLASSROOM

by

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DEDICATION

For my husband Aaron, my best friend and the love of my life. Everything I could ever wish for has come true because of your dedication and endless love. Thank you for supporting my dreams and always listening to my many science adventures. You are my rock. To my two handsome sons, Rylan and Archer. You have made me stronger, more joyful and more fulfilled than I could have ever imagined. I love you to the moon and back.

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ABSTRACT

The COVID-19 pandemic impacted education by removing science from physical classrooms. Adopting remote learning in the fall of 2021 brought new challenges for hands-on discovery and engagement in scientific experiences for my microbiology students. The goal of this study was to assess the impact participation in citizen science had on student motivation, epistemic beliefs toward science, understanding the process of science, as well as value of data contributed by peers. The traditional curriculum was modified to include online collaboration and discussions by students to solve a real-world problem related to a potential public health threat by integrating a series of inquiry-based exercises. The project, Discover the Microbes Within: The *Wolbachia* Project, allowed students to partner with Vanderbilt University and join researchers from all over the world to study and understand the prevalence of this naturally occurring intracellular parasite. Students spent time exploring their community and collected specimens of native arthropods in and around the Toledo campus of Owens Community College. Students worked in small strategic online breakout groups and took on one of three roles; microbiologist, epidemiologist, and reproductive specialist as part of their research to validate claims regarding health threats. Students prepared and reported back to the class their proposal and task force recommendation to submit to the CDC. Students conducted online activities exploring biotechnology techniques (i.e., polymerase chain reaction, gel electrophoresis, Sanger sequencing, bioinformatics etc.) that promoted scientific literacy and problem-based learning outside a traditional classroom setting. Pre- and post-Likert scales were utilized to compare science motivation, scientific literacy, and opinions toward science and technology. A WebQuest online group evaluation, interviews and written response to discussion board forums were used as data collection instruments. Data were processed using both quantitative and qualitative analysis strategies. Students reported that they felt they were learning the same if not more online compared to face-to-face instruction at the end of the semester. The results suggested that students took a more proactive role in their education, self-identified more as "real" scientists, and made positive growth with respect to epistemic beliefs toward science when given meaningful examples that make local connections during remote instruction.

INTRODUCTION AND BACKGROUND

Introduction

Northwest Ohio is home to a recovering economy supported by manufacturing, health care and social assistance, and retail trade. Toledo is well known for its industry, particularly in auto assembly and glass, which explains the city's nickname "The Glass City." The greater Toledo area offers tremendous opportunity for entrepreneurs, cultural experiences, and remains an affordable place to live. Despite recent progress many challenges still face the metropolitan area that negatively impact education in an urban district. In 2019, the median annual household income grew by 2.35% and was $36,709, which is less than the median annual income of $65,712 across the entire United States. According to a report by the Thomas Fordham Institute-5th ed. Ohio Education by the Numbers, "The percentage of economically disadvantaged students has increased significantly since 2005-06." The Census Bureau determined, "25.5% of the population for whom poverty status is determined in Toledo, OH (68.5K out of 269k people) live below the poverty line, a number that is higher than the national average of 12.3%. In Toledo, the largest demographic at any age living in poverty are females. The most common racial or ethnic group living below the poverty line in Toledo is White, followed by Black and Hispanic. The Toledo Public School (TPS) district is categorized as urban: high student poverty based off the Ohio Department of Education's School District Typology report. The Ohio Department of Education has considered the TPS district for years to be in "Academic Distress" until this past year. In 2014-15 the report card for TPS contained two F grades, one for a graduation rate of 64 percent and the second for K-3 literacy. The graduation rate for all students in 2019 reached 79.2 percent, up from 71.4 percent in 2018. The most recent report card for TPS indicates a graduation rate of 82.3 percent in 2020. The biggest barrier for many TPS students considering post-secondary options boils down to finances. Three of the four largest public-school districts in counties surrounding Owens Community College (OCC) are rated to some degree as having students in poverty. Local in demand jobs, like nursing and skilled trades, require access to affordable college degrees or certificates.

Owens Community College (OCC) recognized the unique challenges facing TPS graduates and implemented the Owens Success Program. Any TPS student that shows financial need on the Free Application for Federal Student Aid can now attend OCC for free. The program requires students to be enrolled full time and allows for three years to complete their studies with no out of pocket expense. The Owens Foundation will pick up the tab for whatever state and federal grants don't cover. The college also provides an on-campus food pantry, computer loaner program, as well as a "dress for success" clothing store accessible free of charge to all students. Community partners and alumni help through generous donations to make this available to all students. As a result of these efforts, OCC has served over 11,000 TPS students who earned more than 8,000 degree and certificates over the past decade. OCC also impacted the regional economy by supporting more than 10,700 jobs and provided training to over 140 local companies

Owens Community College is a public community college with campuses in Toledo and Findlay, Ohio. Owens was founded in 1965 in Toledo and chartered in 1967. The Findlay campus opened in 1983. The college prides itself on being the most affordable and supportive option for students looking to learn a trade, earn an associate degree, or transfer to a four-year institution. Owens has 100% admittance policy and works to help nontraditional students find their unique path to success. The college's statement of purpose is to improve lives and enrich our communities. We believe in serving our students and our communities. The current enrollment is 9,460 students with almost 30% registered full-time. Class sizes are kept small and on average the student: teacher ratio is 14:1. The college's overall diversity ranking is slightly above average, and a majority of students require remedial services and financial assistance to attend. The Toledo campus is uniquely situated in a suburb minutes from downtown and equally distant from small rural communities. In the past, I have had students take cabs and/or Ubers to reach campus, skip class due to lack of transportation, or email that they couldn't afford gas. The college now offers a free bus shuttle that connects to public transportation in downtown Toledo. There are many unique challenges facing a majority of our students and as community leaders we are dedicated to making higher education accessible and a reality for everyone.

This fall was the start of my 15th year teaching within the school of S.T.E.M with emphasis on biology instruction for students choosing careers in a health science field. For many, successfully passing their science prerequisites is the last barrier to apply for selective admission into competitive programs. Student performance, engagement, and attitude toward their prerequisite coursework is poor with many self-reporting a dislike for science. Historic data show students who fail courses during their second year of college are unlikely to make progress toward graduation and negatively impact STEM retention. A survey was conducted to assess student perspective regarding the value and importance of science last spring. The findings validate previous informal observations that many students do not see themselves as "scientists" or capable of mastering and/or contributing to scientific knowledge. This might be one plausible explanation for the lack of effort, engagement, and authentic learning that tends to occur in traditional classrooms. Students reported that science is valuable, but feel it has nothing to do with them, a true disconnect is felt between the public and experts. Students expressed interest and a desire for more hands-on activities and less formal instruction to stay interested in content. This dialogue and transparency with former students planted the idea to make the move to include more discovery science in a format that supported project-based learning. It became my focus to switch from a passive learning environment to a more independent and interactive learning approach to improve satisfactory learning outcomes.

Background

My action research goal for the capstone project focused on incorporating a citizen science project into my microbiology course to promote engagement during a rapid transition to online learning experienced during the coronavirus disease, COVID-19 pandemic. The purpose of the AR was to introduce inexperienced students to the process of scientific inquiry by promoting direct engagement in data retrieval, analysis, and practice critical thinking skills outside of a traditional classroom. "Real" science and a hands-on approach will help students take ownership of observations, contributions, and invest in educating the public on local issues. The use of creativity, technology, and collaboration with community experts was intended to emphasize the role of individuals and promote further interest in applied science. Registering for microbiology and successful completion is a prerequisite to enter any selective admissions health science program. Students often lack previous general biology experience and self-report a lack of scientific literacy. In this project, I suggested a shift in traditional methodologies was needed to better prepare and encourage genuine interest in science during synchronous delivery. The use of interactive, research-based models like citizen science projects offers a framework that promotes imagination, provides tools for self-reflection, and improves scientific reasoning without typical restrictions or limitations set forth by linear instruction. Student involvement through a citizen science project has the ability to challenge formal education, administrative directives and/or financial limitations, while improving civic engagement centered on the very nature of science. It was my desire to foster a more open, inclusive dialogue between students, professionals, and community leaders that promotes motivation, better attitudes, and respect for the process of science. The design and implementation of citizen science into traditional classroom settings as well as remote learning should strive to make connections to issues faced locally, raise awareness in the public, and provide strategies for increasing civic participation. The overall process should be a positive empowering experience, fun yet challenging, and leave my student with skills to make new scientific connections beyond the classroom. Throughout my teaching experience, I have seen students rely on memorizing information for assessment only. These students often lack the required skills to apply what they know outside of the classroom and are unable to see the bigger picture. I decided my action research needed to address this concern best by focusing on engagement through citizen science.

Each student can take an active role and is capable of making a difference in research. That was a sentiment I wanted my students to hear loudly and believe by the end of the semester. Students were given the opportunity to use cutting edge technology, work within groups to tackle “real” world problems that made connections to current public health threats, and take ownership in their results based off scientific experiences. Virtual students engaged in developing a hypothesis-driven project, collected data, contributed to datasets, performed analysis and looked for trends to discuss together. A second goal, I wanted to promote emotional meaning and intellectual engagement, increased value for understanding nature, trust in the scientific process through inquiry. I wanted to transform perceived "distant" topics, like emerging disease, into meaningful conversations central to their everyday lives and career. The purpose of this project was to assess whether those goals can be achieved through the integration of a citizen science project as one strategy that leads to greater interest, engagement, and achievement on standard assessment for STEM students. How might participation in citizen science contribute to engagement in an online learning community? What is the effect on student awareness and involvement concerning local issues facing the community? What observations can be made locally? Can students make connections to their own lives, understand the importance of learning about scientific investigations, and value scientific experiences?

Focus Question

The focus question for this study was, How does citizen science affect interest in microbiology, civic awareness, and understanding of the scientific process?

My sub-questions include the following:

1. What is the impact on students' motivation and engagement in online learning after participating in a citizen science project?
2. How does participation in a citizen science project impact students' epistemic attitudes towards science?

3. What is the impact on students’ understanding of the process of science and value of data contributed by peers?

CONCEPTUAL FRAMEWORK

The articles in this literature review supported the inclusion of citizen science participation and addition of interactive online collaborative group activities to the current synchronous learning platform. The changes would not only introduce students to "real" science but increase student motivation, improve scientific literacy, and civic awareness that results in better knowledge regarding the nature of science. The following projects have demonstrated the potential of citizen science as an effective mode for educating students about the processes and content of science at all grade levels. Citizen science allows teachers to facilitate learning by incorporating the use of multimedia, social networks, and making liberal art connections, while simultaneously empowering student creativity which leads to greater interest. A validated framework situated in a real-world context will encourage my students to analyze and interpret data through participation in authentic scientific research resulting in increased appreciation for the relevance of material.

What Makes a Good Citizen Scientist?

Engagement, interest, and relevance. These are three essential requirements that need nurtured in our communities to support citizen science efforts. The power of citizen scientist projects lies in part their ability to mobilize people from all walks of life to contribute to real science. The community college setting is similarly diverse and the perfect setting to engage students by tapping into their unique experiences, skill sets, and career goals. Passion and curiosity to learn more about the natural world through hands-on activities can be conducted everywhere by anyone. In the United States, we know students' interest in science declines as they progress through school (Archer et al., 2010; Povin & Hasni, 2014). Many of my students self-reported previously failing or struggling in formal science coursework which caused them to lose confidence. The loss of interest has been attributed to several factors: a lack of science mentors and role models, unengaging pedagogical practices, perceptions of science classes and careers as difficult, lack of familial support, and competing personal interests (Aschbacher, Li, & Roth, 2010; Carlone, Scott & Lowder, 2014; Lyons, 2006; Vedder-Weiss & Fortus, 2011). In several studies, students reported a lack of meaningful projects as a reason for their loss of interest in science careers (Lyons, 2006). Projects that make local connections or get students excited to learn about career choices increase interest. As educators, we know that genuine interest in content predicts long-term application of scientific knowledge and value of science. Anyone can be a citizen scientist and contribute data alongside professional researchers when given the right tools. Community college students have inherent challenges as they pursue higher education during the COVID-19 pandemic; like budgeting finances, balancing a busy home life, demands of children and/or spouse, technology challenges, working full-time or part-time all while dealing with increased stress and anxiety. The key for my students to become citizen scientists is to address their concerns and make positive learning experiences that maximize our limited time together.

Value of Citizen Science Contributions in Research

Current literature supports citizen science as a strategy to improve motivation, positive attitudes, and increase scientific literacy in primary, secondary, and post-secondary education. Integrating citizen science promotes collaboration between students, allows for increased time spent in nature, and makes possible community connections surrounding local issues students may be unaware of. Student contributions to scientific research are valuable and have been demonstrated to be reliable. A study by Krabbenhoft et al. (2020) discussed the challenges for gaining acceptance and trust with data reported by citizen science projects. It summarized results from site-specific comparisons between quantitative ecological monitoring data and qualitative data generated by volunteers (public). The sites selected and agencies involved are similar to ones used within my own project. Urban stream quality was assessed with analogous sampling at seven locations over three years using quantitative methods and compared to data generated from two citizen science monitoring efforts. The results showed differences between qualitative and quantitative invertebrate assemblage reporting impacting the designated quality of streams but was most likely due to under-sampling or naturally rare taxa. The methods had a lot of overlap and similarity which demonstrates the value of citizen data in contributing long-term site assessment. The results suggested that citizen science was effective and a valid form of data retrieval when paired as a complement to traditional monitoring practices. This study took advantage of public survey information generated by ongoing citizen science monitoring efforts and was a possible source of qualitative data to be used in comparison of local efforts. The findings also demonstrated the continued need for informed public volunteers and support for new citizen science projects. Another related study, Schneider-Opel et al. (2020), supported that implementing citizen science improved biodiversity literacy and is an effective tool for increasing student confidence during discussions.

Support for the Inclusion of Digital Media in Citizen Science

A study by Rivet et al. (2004) discussed the potential use of digital photography to support student inquiry with emphasis on real-world settings (natural phenomena). Middle school students investigated a local stream and were given the opportunity to capture images with digital cameras. The images were used as one form of measure to determine overall health, and function of the stream. In addition to generating images, students performed a series of quantitative tests over water quality. Images were incorporated into media and webpage designs and presented to the community upon completion of analysis. The digital photography project was associated with time students spent thinking about and studying their ecosystem. The pictures were a reference that students shared with one another and facilitated communication. Students reported increased interest and did not require training to be proficient in technology. This was a static measure that could've benefited from digital photography performed over multiple changing seasons and/or continuous monitoring. Changes in water level, plant growth, soil erosion etc. for the area could be integrated with specific quantitative tests to reinforce ecological principles. Instead of focusing on just numerical data this study revealed student's reporting better appreciation or holistic nature of the stream after participation. My conceptual framework attempted to blend students' personal interests like art, web design, and social media in every step of the process of scientific investigation. Students used digital cameras, smartphones, and other readily available devices to capture insect images in the field (OCC Toledo Campus) and modified them at a later date without requiring tremendous training, resources, or rigid timeline. Student generated images were uploaded to discussion board forums and later contributed to a global database. Students were given the choice and ability to choose their local collection site or attend a group collection event on campus. Choice encouraged participation, creativity, and ownership of images. Students without prompting were observed helping one another handle insects and edit images. The interaction and conversation between students increased and encouraged groups to ask questions.

Citizen Science and Social Media

Social networks are everywhere and most students in college have accounts that allow them to watch multimedia resources and even produce them. Dependence on smartphones doesn't discriminate by age or technical experience. What if online social platforms could be used to motivate and enhance participation in educational activities? Collaborative e-learning has become appealing to students as well as educational institutions. The rapid evolution and transformation of technologies presents a challenge to educators to stay up to date. Educators need training on technologies available and discusses options to improve Learning Management Systems (LMS) that support better multimedia content delivery and methods for evaluation. OCC offers extensive professional training every semester on Blackboard and I have blended for a decade a hybrid instructional model to deliver course content. The coronavirus disease, COVID-19 pandemic, took science classes out of my physical classroom completely. There was little training or model to transition courses like microbiology to ensure best practices were being used. To address these growing concerns, the Communica-Media project (http://innovacioneducativa.upm.es/cyberaula.inicio) was designed as a didactic model to validate the potential in existing LMS combined with new e-learning approaches. The goal of a study conducted by Enrique (2014) was a model to foster collaborative e-learning, multimedia use, and multimedia production within nontraditional learning. The increased online sections at my institution required a shift in my pedagogical thinking to include more support for engaged learning through social interactions on a computer. I decided to incorporate parts of this model into my framework and used multimedia to motivate students. The study suggested that multimedia would be more effective for abstract conceptual and theoretical content material than quantitative areas (where students traditionally struggle with complex problem-solving, analysis, etc.) This would prove to be a valuable asset in my assessment tool bag on student learning and impact on collaboration in a digital environment versus traditional instruction. Remote learning could be done better at my institution and one solution was to incorporate more active learning methodologies. In order to enhance learning, the model provided options for using peer-assessments. Designing activities to promote participation with and among students has been key in both asynchronous and/or synchronous online delivery. The application of the model gives rise to five activities: multimedia resource review, questionnaire, collaboration tool, multimedia resource creation, and classmates' multimedia resources evaluation. The activities serve as a guideline and were adapted to my specific course within Blackboard. Qualitative and quantitative data (5-point Likert scale questionnaire) including students' opinions were collected at the end of the model. The students in the model obtained on average better test results and showed more engagement through forum discussions to collaborate with one another. I already used forums within my course but needed to execute better designs that promoted more participation. The ability to respond to student concerns and questions in the LMS, Blackboard, was selected to encourage feedback from peers during the transition to synchronous delivery. In a remote learning survey (Appendix E), 100 percent of my students indicated they had access to a phone and internet ready device such as a computer or iPad in order to participate in discussion board forums.

Liberal Art Connections in Citizen Science

The results from a study by Bozzone (2017) provided a model for authentically connecting liberal arts into science instruction with meaningful results. Students who do not major in science are not “dumb” but “different” and this distinction needs more attention. The majority of students taking microbiology enroll because they have to not necessarily want to which is similar to non-major students taking an elective to fulfill a graduation requirement. Many will not go on to take another general science course. My approach attempted to help students make connections between societal issues and scientific research. I designed and constructed my project to be multidisciplinary and supportive of the arts (a more integrated approach compared to my current framework). Exploring biology with a specific interest in non-majors is exactly what this article discussed. I suspected that what might work for this group of students would work for health science majors as well. There are lots of different learning approaches to knowing or gaining knowledge. I thought for this particular cohort of students there needs to be an emotional investment tied to the content. The authors discussed designing science curriculum with emphasis on the human dimension. Incorporating readings and asking students to explore the topic from a social and biological perspective. They also used a lot of historical misconceptions compared to present day learned events that students could relate to. I had not initially thought of using social perspectives but readily changed my mind after reviewing traditional units to include these elements to engage in better communication. That communication could be used to make the missing connections so many students reported were missing in early surveys. The other key that made this article useful is the recognized value of making community connections. This study partnered with the Boys and Girls Club which offered additional opportunities for inquiry and hands-on learning. Students were supported, creativity was fostered, and many diverse projects originated from these interactions. The learning process allowed for students to rework problems, practice active reading, and develop writing portfolios. The study concluded that an integrated approach to course instruction was more successful for both the students and the teachers. The emphasis on the narrative and commitment to incorporate liberal arts had positive indicators for overall course satisfaction and engagement. The historical or "lived" events were the most surprising in that student generated questions increased significantly. I found and used similar case stories that are specific to the local community and medically significant diseases of early Ohio settlers. It was my hypothesis that many students would show renewed interest in a topic if similar historical connections could be made or applied to future scenarios. The intended outcome was to increase the enjoyment and time spent reading literature.

Citizen Science Design and Implementation for Post-Secondary Education

A paper by Davies et al. (2016) provided a brief introduction to the increasingly popular use of citizen science in formal education. In 2007, the Open Air Laboratories (OPAL) program was launched in England as a network to encourage the design, partnership, methods and impact of citizen science projects. The article followed from conception through implementation the multifarious forms that citizen projects can take and established a base framework. The framework focused on shifting from a passive public that benefits from scientific endeavors to a contributing, valued, and scientifically literate partnership. The drivers for OPAL focused on the following societal concerns: sustainable development, biological diversity, climate change, decline in outdoor education, and loss of global ecosystems. Change required effort and education. The OPAL program has dedicated itself to the cause of promoting the public into active research. The benefit besides collecting data was a change in attitude, investment, and understanding in environmental issues impacting daily life for everyone. This network supports five key objectives that really resonate with the goals of my own project.

Opal Goals:

1. Support a change of lifestyle, a purpose to spend more time outdoors and making observations with an emphasis on local environment.
2. Develop and design exciting and innovative educational programs (accessible by all demographics).
3. Inspire a new generation of environmentalists (scientists).
4. Demonstrate greater understanding of nature and policy
5. Build stronger partnerships between the community, volunteers, and experts.

The methods outlined were straight forward. Recognize and develop a relationship (especially in deprived communities and among minority groups) that builds trust, collaboration, and engagement by suppling the right materials/resources, along with face-to-face positive interactions. Design digital tools and media as downloadable resources that are free for everyone. Provide training and offer online options through apps like iSpot or INaturalist.org to encourage interest. This was important to recognize as I balanced the need for technology against cost and time commitments. Interactive social networks appear throughout the framework and appear to be the mode of choice in public communication. My initial survey to students indicated that most were comfortable with social media platforms. Just as OPAL discussed, my goal was to involve the widest possible audience in data gathering and my classrooms had demographics similar to those cited in public projects. The OPAL project was very clear in defining objective and steps to achieve goals. This framework mirrors other steps identified by similar studies to focus on a research question, identify your "team", and design methods that promote civic engagement. Following basic guidelines there are endless opportunities to design, develop, and promote civic engagement in formal educational settings while building an informed public.

How to Assess Science Skills and Knowledge Through Citizen Science Projects

"Interest, or the perceived personal relevance of a subject, action, or cause, serves as a precursor to knowledge gain, as increased interest can promote learning and engagement" (Phillips et al., 2015). Assessment of citizen science impacts in formal educational settings needs to include measurement of student interest and changes in epistemic beliefs. Efficacy is defined as a person's beliefs about his/her capabilities to learn specific content and to perform particular behaviors (Porticella et al., 2017); it can therefore influence both learning and skill acquisition, providing a bridge between acquired knowledge and its application. For example, research on environmental literacy suggested interest and efficacy may be key precursors to pro-environmental action (Szczytko et al., 2019). Together, interest and efficacy for science and the environment are powerful predictors of learning outcomes to consider in assessments of educational interventions, especially those that contain a citizen science component (Peter et al., 2019; Phillips et al., 2018). This point is reflected in my sub-focus question that looked to see if citizen science transformed attitudes toward learning science. I wanted to include measures for feelings of self-efficacy and confidence with respect to conducting science or interpreting and applying scientific data. Citizen science can support participants while developing their critical thinking and scientific skills to address future environmental issues. Individual motivations for engaging in citizen science can also influence learning and participation outcomes (Larson et al., 2020). Citizen science assignments in the formal education sector may not achieve desired goals if participation is mandated and based solely on extrinsic motivators, such as grades. Conversely, assignments that allow for student choice promote autonomy in decision making, a critical element of Self-Determination Theory (Ryan & Deci, 2000). Autonomy can fuel intrinsic motivation, which positively affects the perceived quality of engagement and learning outcomes, especially for activities related to science and the environment (Darner, 2009).

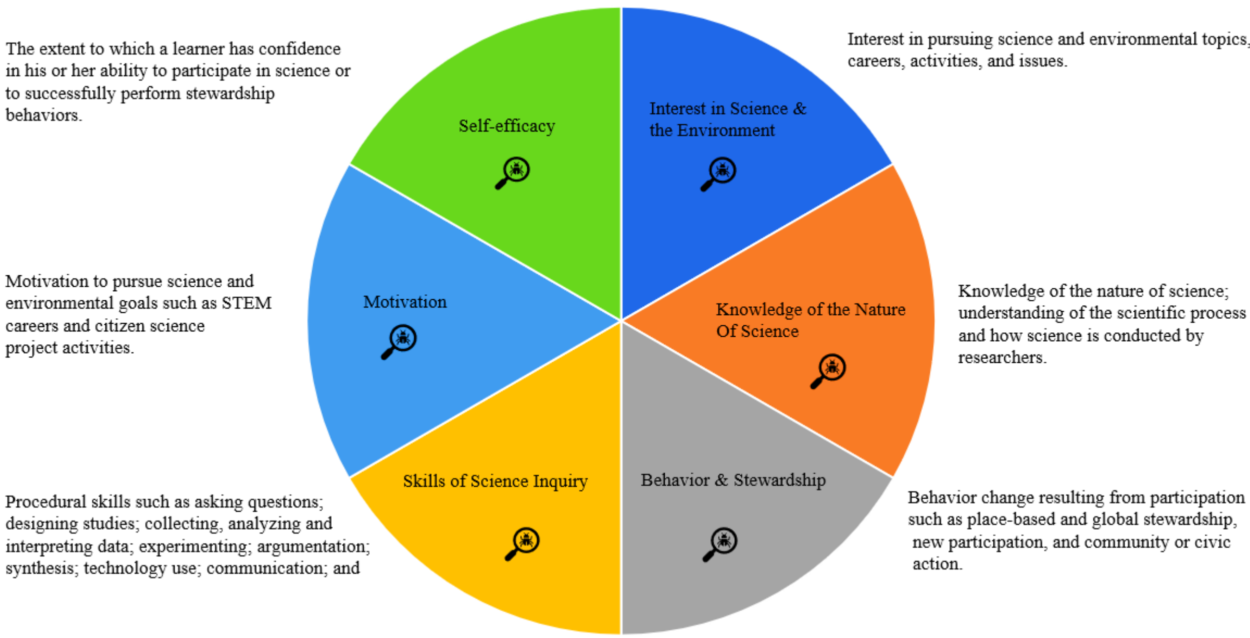

Figure 1. Proposed framework for evaluating citizen science learning outcomes. Adapted with permission from Cornell University, www.birds.cornell.edu

How to Study the Impacts of Citizen Science Projects on Students

Most research on citizen science in formal educational settings has focused on content-specific learning outcomes, including impacts on course grades, content knowledge, scientific reasoning, and understanding of the scientific process (Caruso et al., 2016; Straub, 2020; Voss & Cooper, 2010). However, other possible outcomes of citizen science, such as increasing connections to science and nature, are equally critical for preparing college students to be members of a scientifically literate, environmentally engaged public (Falk & Storksdieck, 2010; Rosa, Profice, & Collado, 2018; Saribas, Kucuk, & Ertepinar, 2017). Furthermore, a recent study of German secondary-school students participating in a biodiversity-themed citizen science project demonstrated that students with higher subject fascination also showed higher long-term knowledge retention (Schneiderhan-Opel & Bogner, 2020), suggesting a critical connection between subject knowledge and affective factors such as interest that stimulate other learning outcomes. Given its general public appeal, citizen science may be particularly well positioned to influence learning outcomes among students who demonstrate low preexisting interest in the environment or who are not science majors. For example, in a study of college students in an entomology course designed for non-science majors, Vitone et al. (2016) found that participation in citizen science improved student attitudes toward science. Caruso et al. (2016) showed that non-science majors participating in citizen science as part of an introductory biology course demonstrated significantly higher course grades and critical thinking skills, as well as higher engagement than students who did not participate in the citizen science project.

Table 1. Sample goals, outcomes, and indicators for existing citizen science project.

Educational Goals	**Potential Outcomes**	**Potential Indicators**	**Project Name**
Increase interest in science activities such as monitoring rare plant species.	Participants gain interest in plant conservation and management.	Increase in the number of monitoring hours logged by participants.	Plants of Concern
Increase in awareness of environmental topics such as marine habitat preservation.	Monitoring of sites will raise individual awareness of surrounding marine habitat.	Volunteers express increased interest in protecting local marine habitats following participation.	Shorekeeper's Guide
Increase efficacy of volunteers to promote wetland conservation and land stewardship.	Volunteers engage in public awareness of water quality issues and take part in local stewardship practices.	Participants use data collected to create and share reports on wetland health to local community.	Watershed Land Trust Adopt-A-Wetland Program
Empower participants to feel part of the scientific process.	Participation results in increased confidence to successfully collect and submit data.	Participants report improved confidence in their ability to contribute to science, increased reports of "self as scientist".	The Great Backyard Bird Count
Increase motivation by local people to understand and monitor their water resources.	Participants are empowered to understand and engage in science activities and environmental action.	Participants express intention to use information in the database to engage in dialogue with local resource management organizations.	Community Science Institute
Increase motivation for learning about the effects of invasive species across the USA.	Participation results in greater intrinsic motivation for learning about specific science topics- such as the spread of invasive species.	Participants report greater personal relevance to learning about invasive species.	National Institute of Invasive Species Science
Increase knowledge of scientific/environmental topics	Participants gain an understanding of firefly biology and habitat.	Participants demonstrate their increased knowledge using online identification tools and exercises.	Firefly Watch
Increase knowledge about the nature of science and science processes.	Participants will demonstrate increased knowledge in two specific areas of scientific problem solving.	Participants complete essay responses for problems regarding causation and correlation.	Spotting the Weedy Invasives
Improve data collection skills.	Participants will be trained to monitor local water quality and collect data.	Participants complete a field training session, and demonstrate gains in sample collection/testing skills.	URI Watershed Watch

Table 1 continued.

Educational Goals	**Potential Outcomes**	**Potential Indicators**	**Project Name**
Provide an authentic science learning environment to impart science inquiry skills.	Participants will practice rigorous collection and analysis of data across upland, freshwater, and coastal ecosystems, practicing scientific processes and protocols using the same field equipment as scientists.	Participants showcase their data and multimedia “meaning-making” projects via interactive website and public discussion.	Vital Signs
Change participant behavior with regard to the spread of invasive species.	Participants will take part in at least one targeted behavior such as actively removing invasive species from their homes and/or neighborhoods.	Participants will report a change in their behavior regarding invasive species (4 target areas: eco management, persuasion, policy/legal means, and consumer choices).	Spotting the Weedy Invasives
Encourage participants to engage in community coalitions.	Build a network of informed citizen advocates for management and protection of natural resources.	Evidence of active community networks built through participation in group monitoring events.	Water Action Volunteers

Note: Content has been included and modified with consent of projects listed here. Colors are representative of the framework in Figure 1.

Instruments and Methods for Evaluating Citizen Science Impacts on Students

Instruments for evaluation of citizen science can include protocols for interviews, observation, or focus groups; surveys and questionnaires; checklists; rating scales; and tests and quizzes. Instruments are defined as tools used to collect and organize information about project participants either through self-reports or observations. The literature review discussed best practices with regard to choosing the best measure for outcomes into three choices: 1. use an existing validated instrument; 2. modify an existing instrument; 3. develop your instrument tailored to your needs. An “online toolkit” was developed by The Cornell Lab of Ornithology and contains tested surveys that are contextually relevant to citizen science (Appendix X

Screenshot of toolkit, www.citizenscience.org/evaluation). Figure 2 below shows a comparison between quantitative and qualitative study evaluation designs with supporting data collection types used in my action research. The vast majority of projects in my literature review supported the use of a mixed method approach for measuring motivation and efficacy.

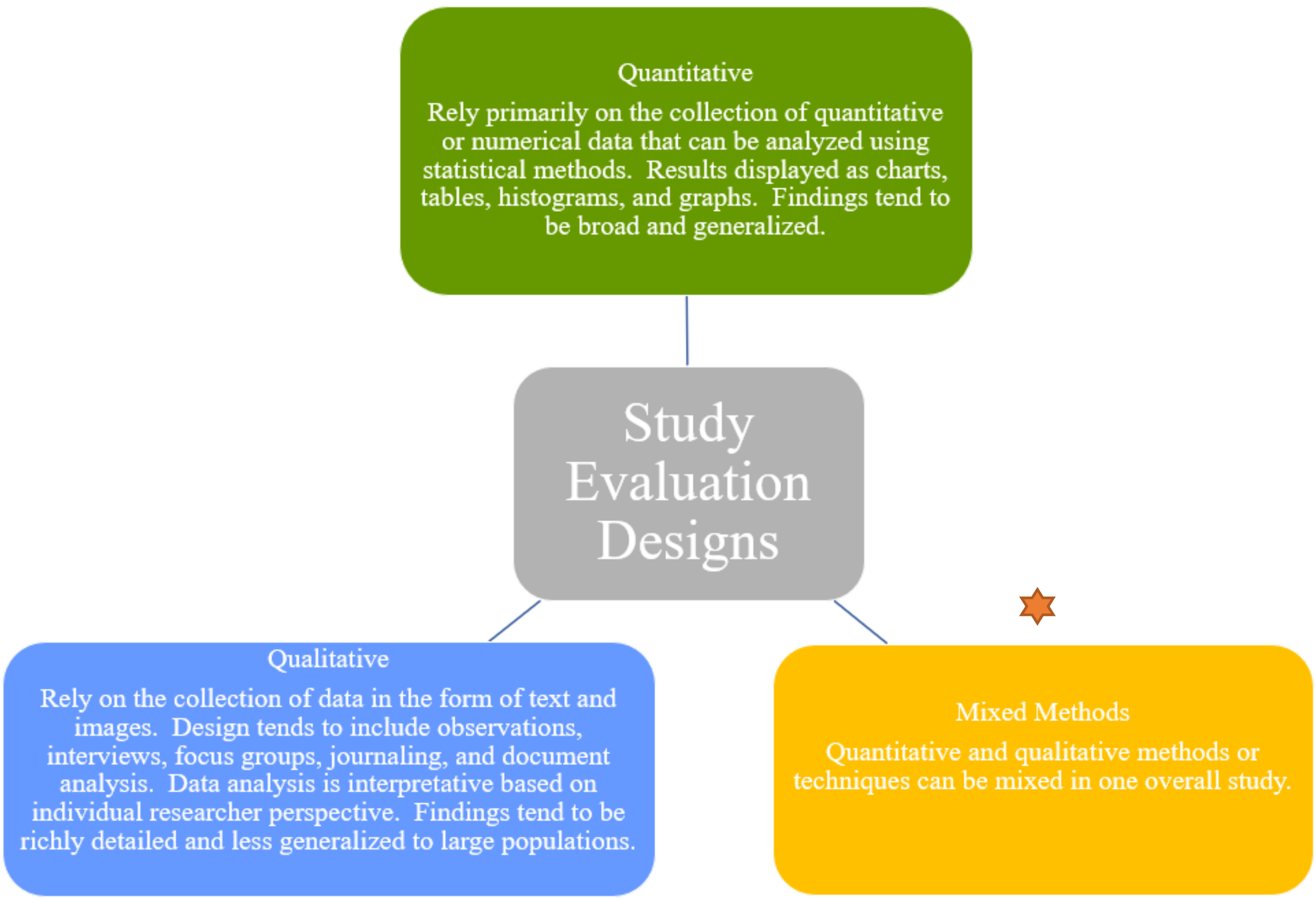

Figure 2. Comparison of study evaluation designs. ★ Marks the design used in my action research. Adapted from Friedman (2008) and Creswell (2003).

The ideal project. Discover the Microbes Within: The *Wolbachia* Project, aligned with core content taught in Microbiology and partnered with research experts from the scientific community. The literature review supported the inclusion of project-based learning, incorporating digital media, utilizing social networks, and encouraging creativity with the inclusion of arts to promote engagement and literacy in a synchronous microbiology classroom.

METHODOLOGY

Students participated in citizen science, Discover the Microbes Within, and joined *Wolbachia* researchers to study and understand the prevalence of this naturally occurring intracellular parasite among native arthropods. Students engaged in inquiry, discovery, and critical thinking through a series of integrated labs designed to promote active hands-on learning, investment in science and scientific experiences. Students conducted online activities exploring biotechnology techniques (i.e., polymerase chain reaction, gel electrophoresis, Sanger sequencing, bioinformatics etc.) that promoted scientific literacy and problem-based learning outside a traditional classroom setting. Pre- and post-Likert scales were utilized to compare science motivation, scientific literacy, and opinions toward science and technology. A WebQuest online group evaluation, interviews and written response to discussion board forums were used as data collection instruments. Qualitative and quantitative instruments were selected to identify science motivation and epistemic beliefs toward the process of science pre and post treatment. Here I discuss the timing and use of specific instruments throughout my action research to address my focus question.

Course Description Summary

Students participating in this project were taking a synchronous microbiology lecture as the final biology prerequisite to apply to competitive allied health programs. This course pre-COVID-19 had always been taught in a traditional face-to-face classroom. The rapid transition to virtual teaching required innovative strategies to support and engage students to take an active role in their learning. The only interactivity among students in the traditional course offering came from lecture discussions and informal observations by the teacher regarding topic interest. Students were not given homework and emphasis was placed on formal assessment by way of examination. The switch to synchronous format presented an opportunity to change the course curriculum and improve student motivation and interest in the process of science through participation in a citizen science project. Through a series of guided project-based online activities and direct contribution to "real" science students would make relevant connections to local issues while engaging in meaningful interactions with other students.

Demographics

The audience for my project were community college students enrolled in BIO 231 Microbiology and Immunology in the Fall 2021 semester. Four sections participated with one serving as a control group and three receiving the experimental variable involving citizen science participation. There was a total of 93 students enrolled at the start of the semester compared to 88 the last week of class. Synchronized course offerings cap student enrollment at 25. Students were evenly distributed between the 4 sections with n= 22, n=22, n=24, and n=20 upon course completion. All students received Likert surveys regarding attitude and motivation toward science at the start and end of the semester. Each group received weekly prompts and the opportunity to participate in discussion board forums regarding course content and inquiry. Students were assessed by online activities and traditional exams to compare for treatment effects on engagement. The experimental group was introduced to the concept of citizen science during the first week of the 16-week semester. Students from all sections engaged in an online WebQuest activity (Appendix G) involving the bacterium *Wolbachia* and worked in small breakout groups in Blackboard to critically think about a mystery disease. Students took on designated roles and strategized to present a written solution that prevented a potential public health threat. The three treatment groups received further instruction on *Wolbachia* and engaged in discovery science with the mystery disease for hands-on investigation and monitoring through citizen science. The research methodology for this project received an exemption by Montana State University's Institutional Review Board, and compliance for working with human subjects was maintained (Appendix A).

Treatment

The project took place over 16 weeks during the Fall 2021 semester. Due to OCC's institutional policy and state mandates with regard to the novel coronavirus disease, COVID-19 pandemic, courses were kept online instead of returning to traditional instruction. During the first week of the course, students from three sections were randomly selected to participate in the citizen science project. The students were asked to watch outside of class an online tutorial: Introduction to Citizen Science. The estimated time for students to complete the introduction was 30 minutes. The tutorial is interactive, self-guided, and introduced the who, what, how, and why of citizen science. The tutorial can be run on a computer, ipad, or from a student's smartphone to promote inclusion and equity online. At the end of the module, students after taking several short quizzes were awarded a certificate of completion uploaded to a digital dropbox in Blackboard. The tutorial can be accessed here: https://media.scistarter.org/Tutorials/Intro+to+Citizen+Science_Gen_12052020/story.html. I showed in class, a two-minute video introduction that summarized the intent of citizen science. Through informal questioning students reported no knowledge or first-hand experience with citizen science. Here is the link to the introductory video: https://youtu.be/CN9kcFxUPi0 (Figure 3).

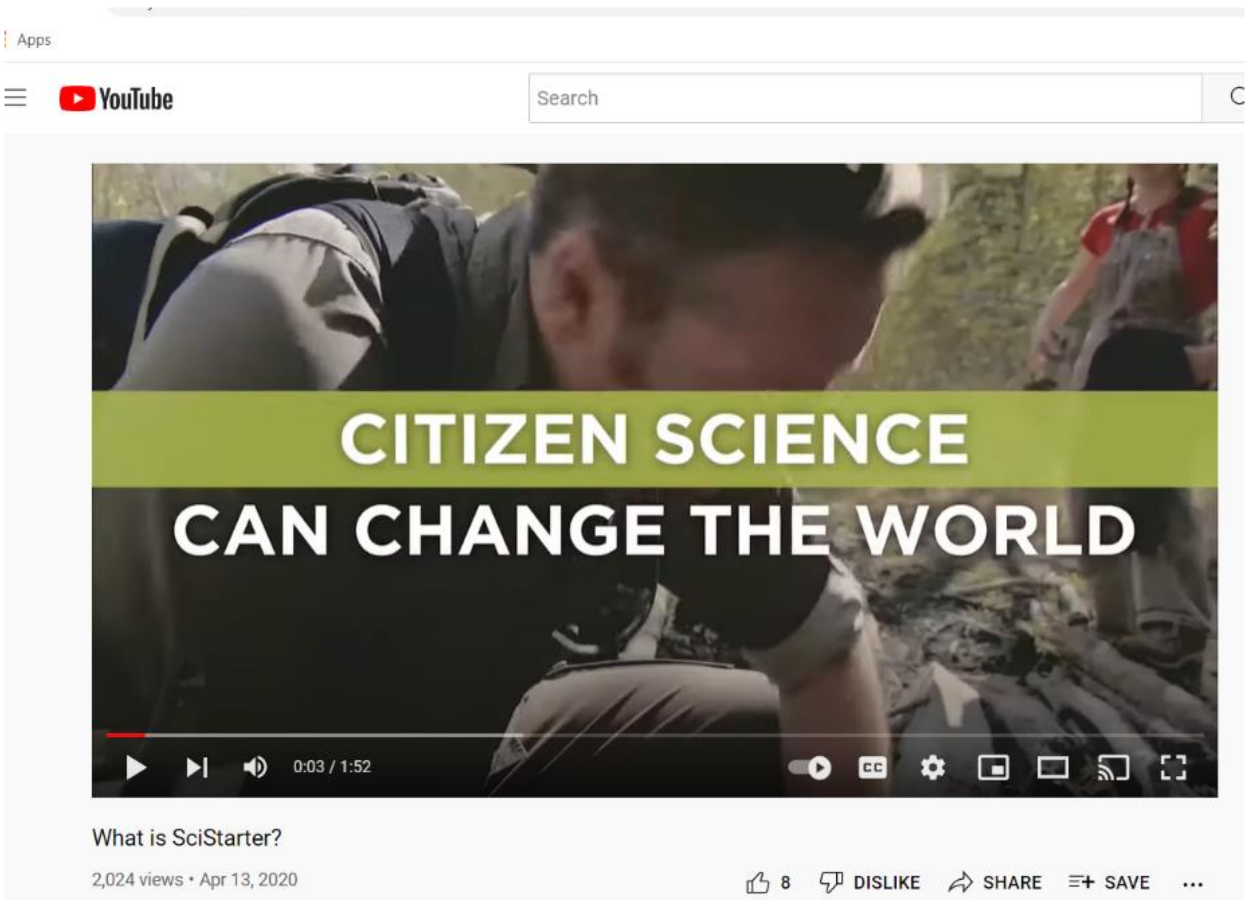

Figure 3. What is SciStarter? Introductory video to citizen science opportunities.

Students were asked to create an account with SciStarter.org and downloaded a free app onto their device. The project URL: https://scistarter.org/discover-the-microbes-within-the-wolbachia-project (Figure 4).

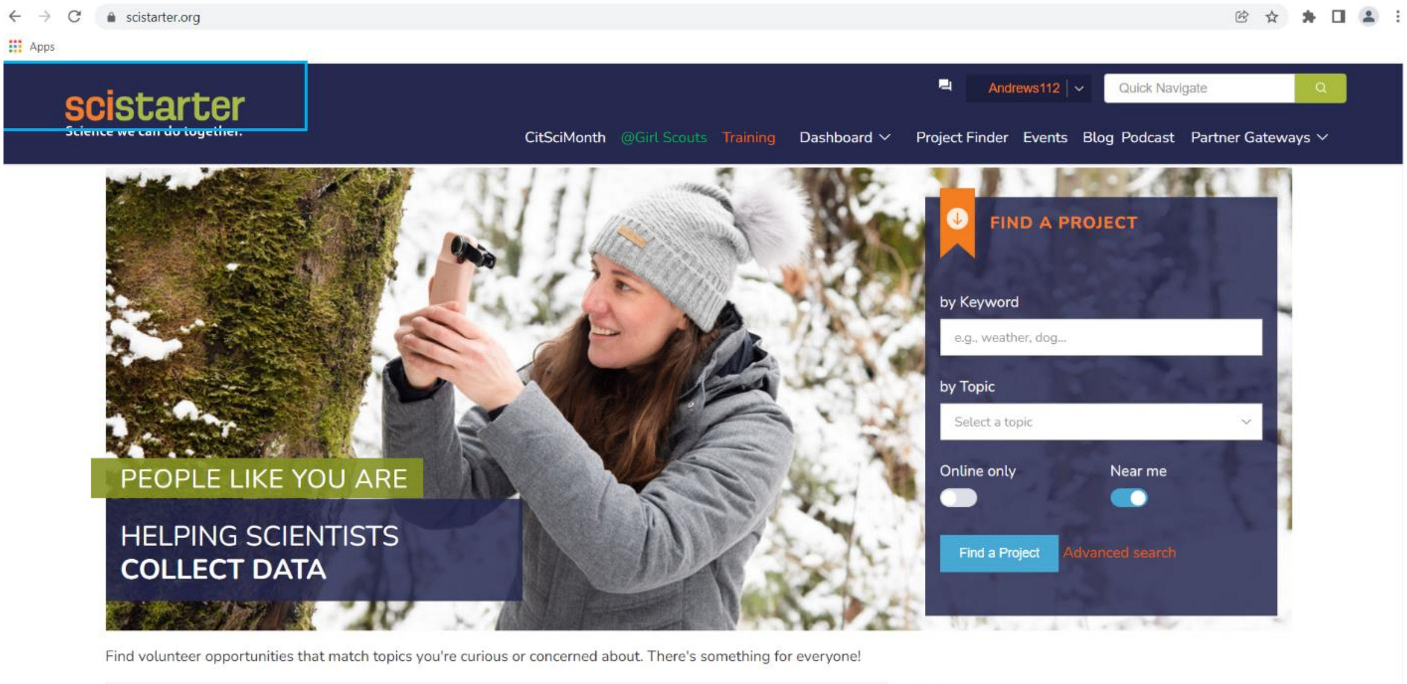

Figure 4. Login and project finder page screenshot.

Data Collection and Analysis Strategies

The *Wolbachia* Project is a ground-breaking national reporting project that combines citizen science, public media, and low technology driven data collection methods with over 15 years of data collection by students. The project uses integrated labs to bring real-world scientific research to any classroom regardless of delivery (Figures 5; Figure 6). Students were offered four optional on campus dates to sign up for the opportunity to work with peers to conduct "real" science.

Figure 5. In-person arthropod collection sites on the Toledo area campus.

Figure 6. Student bench with experimental setup for integrated labs 1-5. Equipment and perishable materials were generously donated by OCC and Vanderbilt University.

Students learned to self-report their own experiences and received the opportunity to interact with experts. Students watched a prerecorded greeting from Dr. Sarah Bordenstein, primary investigator, from Vanderbilt University that developed the lab series. Students in the treatment group received instruction for data collection using text, photos, and stories. Athena Lemon, Project Coordinator, The *Wolbachia* Project, provided detailed recordings demonstrating techniques and tips used during data collection and analysis. Handouts were provided for students to take notes and mark observations. Links to videos were shared to Blackboard for students to review again outside of class. Lab One of the series required students to learn about arthropod collection methods and instructions for identification (Figure 7). Students then spent time outside in a local destination within the community or came to the Toledo campus for a group field work day. Students took digital images of the habitat and insects collected then uploaded the files to a group discussion board to share with one another. Students recorded relevant information regarding site specific data and were asked to write down observations.

Figure 7. Students collecting arthropods for identification.

The second and third lab exercises introduced students to molecular techniques that usually are limited to lecture discussion. Upon completion, students were able to experience and increase their skills in biotechnology. The exercise allowed students to extract and amplify genomic DNA from their own samples. The protocol students worked with came from a commercially available spin column kit, Promega Wizard SV genomic DNA purification system (Figure 8).

Figure 8. Students used pestles to grind insects during Lab 2: DNA Extraction.

The final two labs focused on visualizing the results and data analysis. This exercise combined student scientific discovery with inquiry to improve scientific literacy and knowledge over the scientific process. Students performed and ran agarose gel electrophoresis of samples. The purpose of the gels was for students to determine the presence and size of arthropod genes versus the *Wolbachia* 16S rRNA genes. Students partnered with Vanderbilt University to upload results and contribute to an online global database on the incidence of *Wolbachia* infected arthropods obtained from the local community including the college grounds on the Toledo campus. Bioinformatics and introduction to Sanger sequencing analysis were the focus of the final lab five. Students did not use their own data but DNA sequencing files provided by The *Wolbachia* Project for practice. All the lab exercises can be completed in 60-minute periods but do require time in advance to prepare materials. Exercises were simulated online and allowed virtual students to participate that were unable to come to campus. Students received their packet of training material one week in advance of participation. The packet explained the mission of the project and included colorful figures that detailed the work flow. Students arrived on campus and watched three short training videos over each lab before engaging in data collection and analysis. Link to training material: https://www.vanderbilt.edu/wolbachiaproject/getting-started/. The home page for reporting results was embedded within Blackboard and allowed for single login access. The Blackboard home page was where students reported their observations, read stories, and listened to media updates. Social media, like Twitter, was included for students that agreed to register with personal accounts. Students also were given the option to follow real time updates on The *Wolbachia* Project on many social media platforms including Instagram, Facebook, and YouTube (Figure 9).

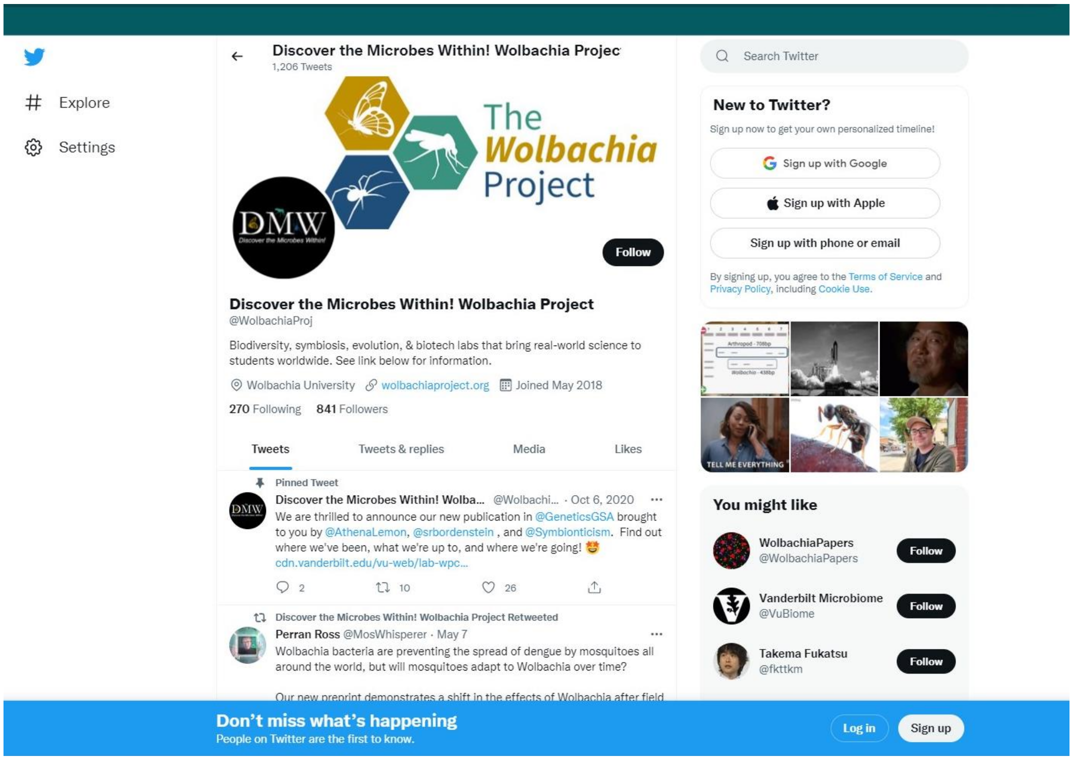

Figure 9. Sample social media opportunity for students.

Students were required to keep journals and report their findings, thoughts, and store image files submitted with all relevant material to Discussion Forums on Blackboard. Once samples were processed students were asked to reflect on what they saw and experienced. Students were randomly selected at the conclusion of the project to participate in an informal interview. Post-treatment surveys were used to qualitatively assess students' understanding on the nature of science, opinion on technology, and value of scientific experiences. Throughout the entire semester students received weekly prompts detect patterns and trends in learning, attitude, and motivation. All students were offered the chance to participate in a Zoom session over the project to increase diversity of response to determine if goals were met as identified in this proposal. The following instruments were used to determine the impact of citizen science participation. I will explain in the following paragraphs how each instrument was used, developed, and demonstrated to be a valid form of assessment (Table 2).

Table 2. Data Triangulation Matrix.

Questions	Data Source 1	Data Source 2	Data Source 3
Sub Q1: What is the impact on students' motivation and engagement in online learning after participating in a citizen science project?	Science Motivation Questionnaire II (SMQ-II) (pre and post)	Student Remote Learning Survey and Open-ended Questions	Informal Teacher Observations
Sub Q2: How does participation in a citizen science project impact students' epistemic attitudes towards science?	Positive Attitude Toward Literacy (pre and post)	Opinion on Science and Technology (pre and post)	Discussion Board Forum and Science Identity Survey
Sub Q3: What is the impact on students' understanding of the process of science and value of data contributed by peers?	Civic Awareness, Engagement, and Perspective (pre-treatment)	WebQuest Group Inquiry Project and Discussion Board Forum	Post Treatment Student Informal Interview and Group Evaluation

Science Motivation Questionnaire (SMQ-II)

A large body of work in the fields of science education and educational psychology indicate that student motivation plays a significant role in science learning and achievement (Brophy, 2013; Bryan et al., 2011; Glynn et al., 2007; Schumm & Bogner, 2016; Wendell et al., 2016). As the United States continues to work to improve scientific literacy and deliver high-quality science education, there is a growing awareness of the need to measure motivational constructs accurately and rigorously (Bond & Fox, 2015; Boone et al., 2014; Glynn et al., 2011; Koballa & Glynn, 2007; Scantlebury et al., 2001; Siegel & Ranney, 2003). The literature review suggested that attitudes and motivation towards learning science are considered reliable predictors of student performance. Factors that influence positive behaviors may lead to higher achievement (Brophy, 2013; Deci & Ryan, 2011; Koballa & Glynn, 2007).

I had often wondered what role motivation played in determining which students excelled in science and which ones struggled. It became clear during my literature review that measuring motivational constructs can prove difficult because motivation, like many other psychological constructs, is a latent variable that is not directly observable (Glynn et al., 2011; Glynn & Koballa, 2006). Measurement instruments have been developed to link unobservable attributes (e.g., levels of motivation) to measurable observations (e.g., responses to questions) (National Research Council, 2001). The SMQ II is an instrument designed to measure student motivation to learn science. Motivational constructs in science attempt to answer the question of why students study science, how long and hard they work at studying science, and their feelings towards science (Koballa & Glynn, 2007).

The Science Motivation Questionnaire II consists of 25 questions and was originally developed in 2011 by Georgia State University researcher, Shawn M. Glynn. This survey was given to my students during the first and last week of the semester. Scale items were developed using the five key constructs of motivation to learn science: intrinsic motivation, grade motivation, career orientation, self -determination, and self-efficacy. Descriptions for each construct are summarized in Table 3.

Table 3. SMQ-II: Proposed factors contributing to motivation to learn science.

SMQ-II Construct	Description
Intrinsic Motivation (& Personal Relevance)	Defined as performing a task or an activity for enjoyment and/or satisfaction, with no external rewards associated with it. Intrinsically motivated students tend to be more eager to learn, more focused, more self-reflective, and more accepting of novel challenges.
Self-determination	Self-determination refers to each person's ability to make choices and manage their own life. Highly self-determined people feel more motivated to act when they feel that what they do will have an effect on the outcome.
Self-efficacy (& Assessment Anxiety)	Self-efficacy is an individual's belief regarding his or her own capabilities. Students with high self-efficacy tend to feel strongly about their ability to perform and achieve.
Career Motivation	Career motivation refers to each person's desire and behavior to exert effort to enhance career goals.
Grade Motivation (& Goal Orientation)	Grades are external or extrinsic motivation.

The SMQ II has demonstrated that the five self-regulatory aspects of motivation were strong predictors of science achievement (Glynn et al., 2011).

Positive Attitude Toward Scientific Literacy Survey

Attitude like motivation is not an observable behavior; it is a trend which prepares the behavior. Attitude may lead behavior and affect academic achievement. Turanli et al. (2008) defined attitude as "a positive or negative position towards a situation, an object, or an action." Attitude is also associated with one's response to anti-ideas and used in evaluation of a person's knowledge (Bilgin & Karaduman, 2005; Pratkanis et al, 1988). The Likert survey (Appendix C) consisted of seven questions and was originally developed for "The Wabash National Study - The Impact of Teaching Practices and Institutional Conditions on Student Growth (2011). The students took the survey during week two and thirteen. The survey assessed effective attitudinal characteristics which cannot be directly observed regarding scientific literacy. The survey was not a measure of student potential. Scenarios were given and scores correlated to students' own willingness.

For the purpose of this study, scientific literacy includes literacy in science and technology. There are many definitions of what scientific literacy should encompass but they all tend to agree and include the skill to apply scientific knowledge as well as thinking for personal and societal objectives. The literature review suggests students who are scientifically literate tend to employ skills, attitudes, values and knowledge which are associated with the nature of science and become lifelong learners. During a 15-year period, Showalter (1974) reviewed and summarized seven different dimensions of scientific literacy:

1. Understanding the nature of science
2. Using scientific concepts, principles of laws and theories in daily life
3. Using scientific processes for problem solving, decision making and developing a perception of universe
4. Relating science and environment by using values which form the basis of science
5. Understanding the relationship between science, technology and society
6. Directing science education towards developing deeper and more satisfactory universal concepts
7. Developing skills which are particularly associated with science and technology (Turgurt, 2005)

My survey takes these elements and included the effect of science and technology on society. The purpose of the survey was to investigate the effect of citizen science participation on scientific literacy and on students' attitudes towards technology. The sub-questions covered were:

1. How does participation in a citizen science project impact students' epistemic attitudes towards science?
2. What is the impact on students' understanding of the process of science and value of data contributed by peers?

Opinion on Science and Technology Survey

Students' attitudes and beliefs towards science and technology may influence their curiosity, cooperation, and critical thinking skills (Harlen, 1998). In addition to attitude, students were assessed on epistemic beliefs regarding the value of science and technology. The survey (Appendix D) consisted of eight questions and was administered week four and fourteen.

Student Remote Learning Survey

This instrument investigated student beliefs and experience with remote learning. I wanted to know if students felt they were capable of learning the same in a remote setting. Did my students have any specific concerns regarding science learning? Before participation in my integrated lab series, it was important to determine if access to digital material was inclusive and equitable for instruction. Student responses could be analyzed for impact of treatment on student perception regarding learning science. Students during week 6 were assessed and self-reported on their individual level of comfort and ease of use regarding online instruction and supportive media. A total of eight questions asked students to rank the most appropriate response and three additional open-ended questions regarding current experience with remote learning (Appendix E).

Civic Awareness, Engagement, and Perspective Survey

During week seven, epistemic beliefs toward science connections, value, and community awareness were investigated. Students were asked who they believed could be "scientists" after looking over 15 images. Students marked either agree or disagree next to each image. The images represented a diverse group of people students generally interacted with in their daily life, community, or saw in the news (Appendix F). The purpose of the survey is to highlight and discuss any perceived bias and/or stereotypes still held by students. A misconception probe was generated from a student comment, "Women are not as encouraged to pursue science because of the stereotype that they are not as good at math as male students." Students were asked to explain why or why not they disagreed with images in breakout groups.

WebQuest Online Introduction: The Microbes Within and Evaluation

During week Nine students were introduced to the WebQuest: The Microbes Within as a precursor activity to participation in their citizen science project (Appendix G). Students had previously learned about obligate intracellular parasites and the bacterium *Wolbachia*. The purpose of the WebQuest was to organize students into small strategic online breakout groups in order to dig deeper and explore any potential public health threats using a real-world example. Each group represented a specialized task force that would report their summary to the Director of the Center for Disease Control (CDC). Students had to actively engage with one another to critically think about the problem, address concerns, and validate claims through evidence-based research. Members of each group took on one of three specific roles; microbiologist, epidemiologist, and reproductive specialist. Students became the teachers and shared information with one another until a consensus was reached regarding a recommendation for action by the task force to prevent a potential pandemic. Each group's report was shared to an online discussion board forum for feedback and questions. At the end of collaboration individual students responded to a group evaluation survey. Students were asked to reflect on the group's dynamics and answer thirteen questions based on their level of agreement with each statement. There were a few specific questions that applied to individual level of participation and engagement as well as one open-ended question for feedback regarding the inquiry activity (Appendix H).

Science Identity Survey

Likert survey and open-ended questions designed to assess during week ten how my students perceive themselves as scientists before engaging in citizen science. The leading question, what is science identity? I wanted to know what I could do to promote and help students self-identify as scientists. Researchers have found that the sense of belonging in science matters more than grades and background when it comes to keeping students in science majors and careers. The concept of science identity is broken down into several components. Carlone and Johnson (2007) defined the elements of science identity as competence (knowledge and understanding science); performance (someone who can use the tools of a scientist, walk the walk, and talk the talk); and recognition (someone who is recognized as a science person by "meaningful others" such as family or researchers). The literature review suggested students with a strong science identity is a validated predictor of academic success. The problem, like in measuring motivation, is that student science identity is subjective and amorphous. I realized an accurate definition of science identity might require redefining traditional notions of science held by adult learners. I have observed students making statements like, "I feel that scientists are considered to be nerds" or "I think you have to be really smart. When I think of a scientist, I think of someone who is so much more intelligent than I am." One of the most repeated comments pertained to receiving an associate degree or learning a skilled trade as less of an accomplishment within STEM. Several students told me, "I am going to be a nurse not a scientist. I don't have the right degree." Science identity may be fully embraced especially in community college students when inquiry and research is equated to lived experiences. Students ranked their level of agreement to three statements and provided extended answer to three open-ended questions (Appendix I).

Citizen Science Participation Informal Interview Questionnaire

Students were informally interviewed during and after participation in citizen science. The citizen science opportunity took place the last week of the semester. Questions looked to evaluate the impact on motivation and attitude from the student perspective. My questions focused on did the students enjoy the experience; would they be willing to participate in citizen science again; and did the hands-on learning add value to their understanding of the scientific process?

DATA ANALYSIS

The goal of my analysis from science questionnaires, surveys, instrument constructs, and interviews was to determine the degree to which particular experiences motivate health science majors to engage in learning science. The instrument results looked to compare the relationship between the components of motivation and other variables, such as: science achievement, science identity and stereotypes, and belief in relevancy of science to a future allied health career. In my hypothesis, I predicted that student participation in a meaningful science activity, like citizen science, would increase motivation and increase understanding of the nature of science. The results suggested that students enjoyed the integrated project-based labs and the opportunity to contribute to an authentic science project. Students on average self-reported an increase in motivation, self-identified as scientists, and took proactive roles in their learning. Students applied scientific knowledge and made connections to raise awareness to local community and global health issues. Results were analyzed using Pearson Correlation, mean score analysis, and standard deviation.

Results

Science Motivation Questionnaire (SMQ II)

The SMQ II is a multidimensional assessment investigating five proposed factors thought to contribute to student science motivation. The five constructs analyzed in my study included: intrinsic motivation, self-determination, self-efficacy, career motivation, and grade motivation. The SMQ II was administered to health science students enrolled in microbiology during the first week of the fall semester 2021 (N=93) and the same population was sampled again during the last week of class (*N*=88). Students from every class on average ranked highest pre and post treatment scales for grade motivation and career motivation. Intrinsic motivation and self-efficacy scales were the lowest mean class scores across groups. Correlations looking at positive and negative relationships between constructs was determined by Pearson correlation results. Figure 10 shows comparison of mean class component score pre and post participation in citizen science.

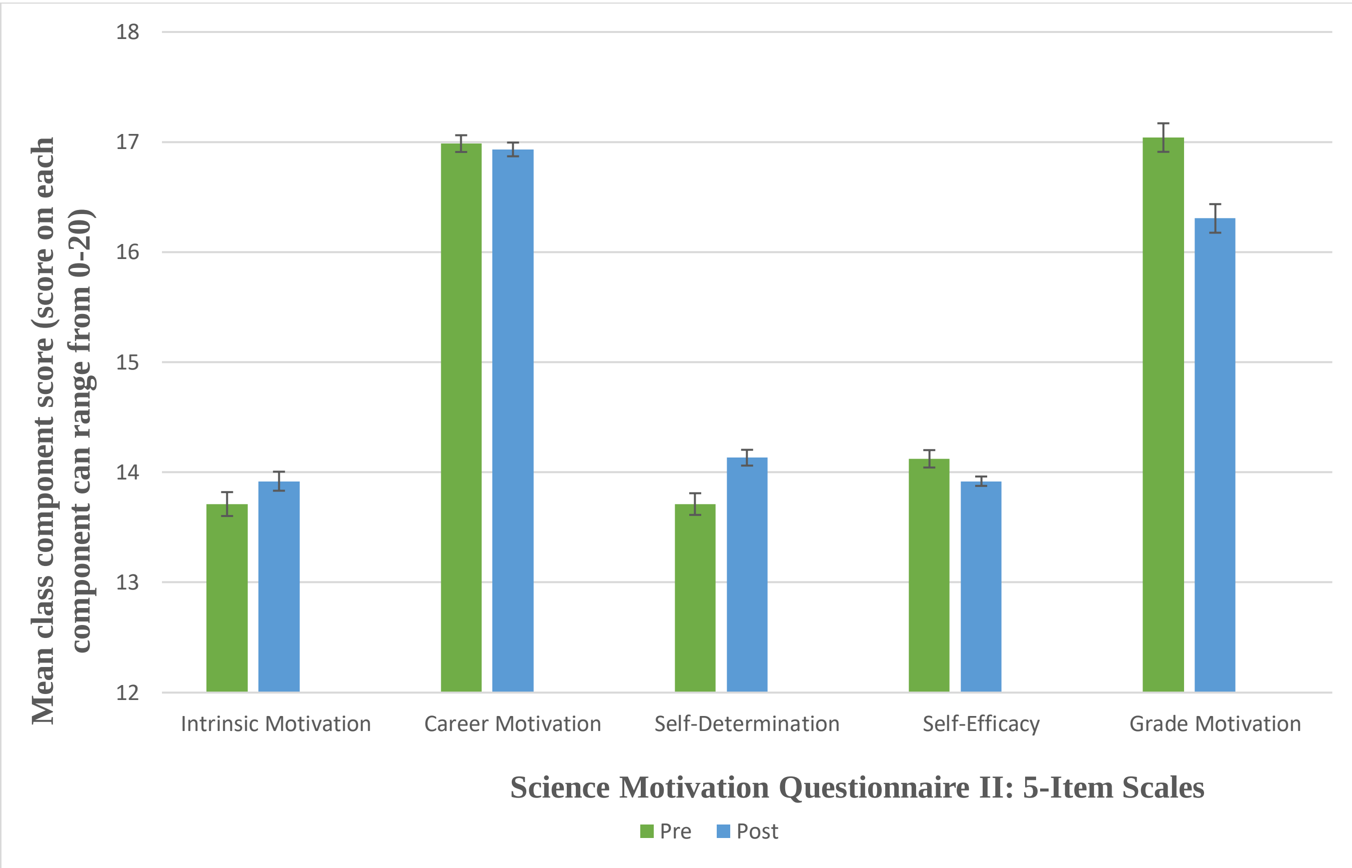

Figure 10. Assessing science motivation in health science students enrolled in a synchronous microbiology lecture pre and post participation in citizen science, (*N*=75).

A Pearson correlation coefficient was computed to assess the linear relationship between intrinsic motivation and self-determination of students after participation in a citizen science project. There was a strong positive correlation between the two variables, r(73)= .81, (p<0.05).

The mean class score for intrinsic motivation and self-determination pre-participation was 13.71 on the Likert scale but rose to 13.92 and 14.13 respectively. The strong positive linear relationship can be seen in Figure 11. This trend was observed in 66% of my data. The strong correlation suggests that students with higher intrinsic motivation on average have increased behaviors related to self-determination. Ryan & Deci (2000) defined intrinsic motivation as the "inherent tendency to seek out novelty and challenges, to extend and exercise one's capacities, to learn and explore." (p. 70). Intrinsic motivation is defined as performing a task or an activity for enjoyment and/or satisfaction, with no external rewards associated with it. Intrinsically motivated students tend to be more eager to learn, more focused, more self- reflective, and self-determined. No extrinsic motivation or grade was given for participation in citizen science.

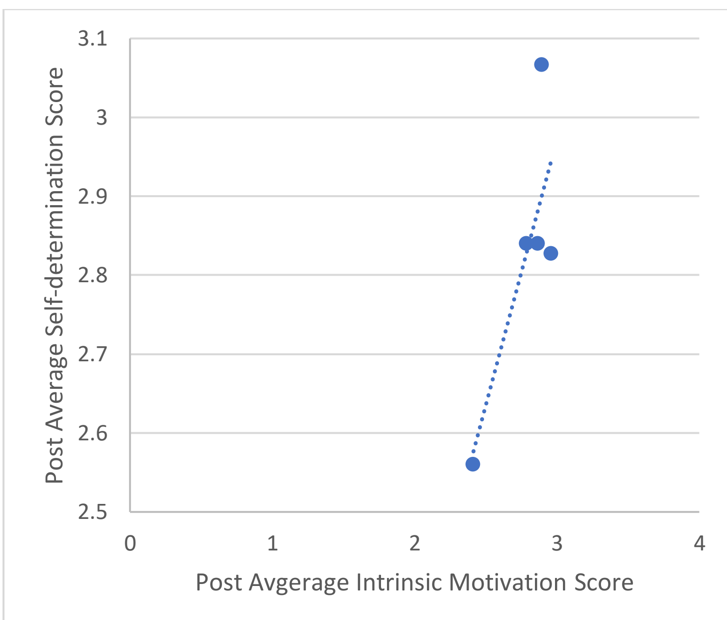

Figure 11. Significant positive correlation between student self-determination and intrinsic motivation mean class scores post treatment, (*N*=75).

A Pearson correlation coefficient was computed to assess the linear relationship between intrinsic motivation and self-efficacy of students after participation in a citizen science project. There was a weak positive correlation that was significant between the two variables, r (73) = .44, ($p<0.05$). This trend was observed in 19% of my data. The pre-mean class score for intrinsic motivation was 13.71 and increased to 13.92 post compared to the mean pre-score of 14.12 that decreased to 13.92 for self-efficacy. This significant correlation suggests that students with higher intrinsic motivation on average experienced higher beliefs in their capacity to achieve academic goals (Figure 12).

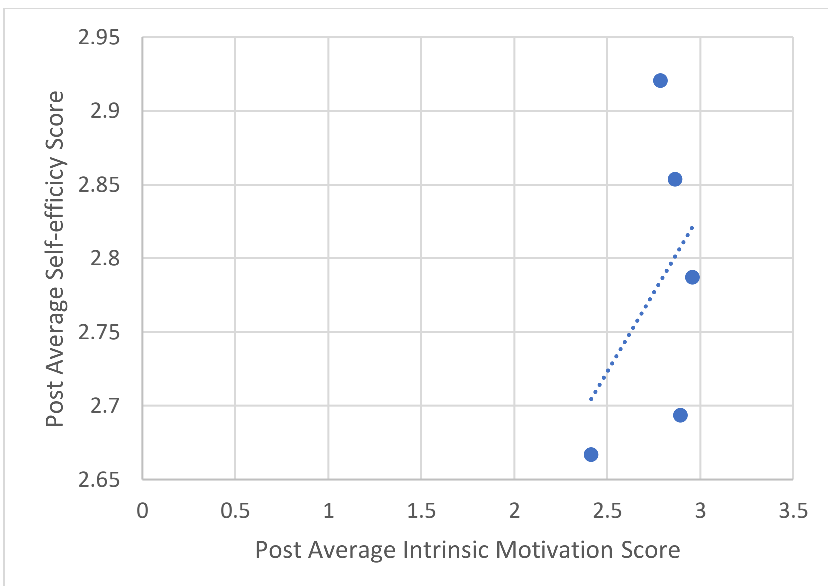

Figure 12. Significant positive correlation between student self-efficacy and intrinsic motivation mean class scores post treatment, (*N*=75).

A Pearson correlation coefficient was computed to assess the linear relationship between intrinsic motivation and career motivation of students after participation in a citizen science project. There was a strong significant negative correlation between the two variables, r (73) = -

0.67, (p<0.05). This trend was observed in 82% of my data. The mean class score for intrinsic motivation pre-was 13.71 and increased to 13.92 post compared to the mean pre-score of 16.99 that decreased to 16.93 for career motivation. On average students were less likely to be motivated by careers when intrinsic motivation increased (Figure 13).

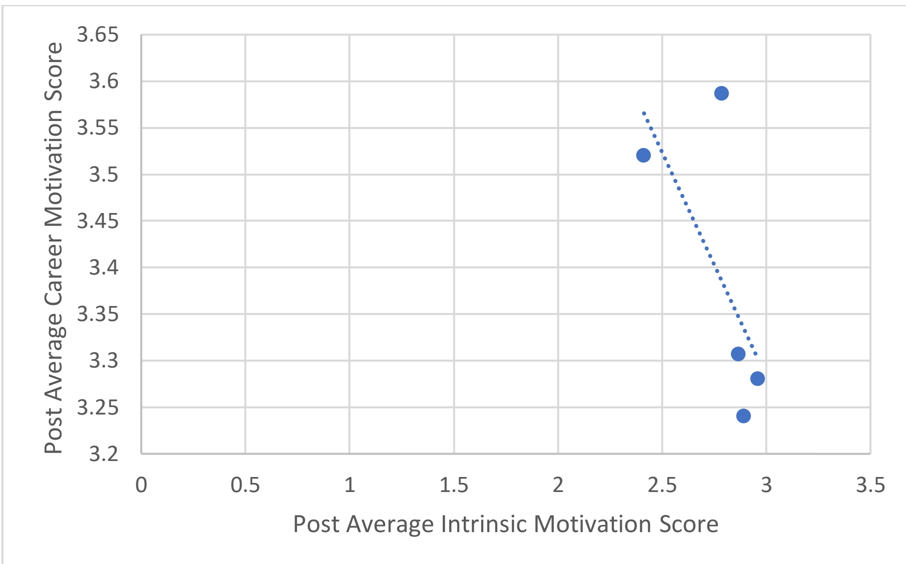

Figure 13. Significant negative correlation between student career motivation and intrinsic motivation mean class scores post treatment, (*N*=75).

A Pearson correlation coefficient was computed to assess the linear relationship between self-determination and career motivation of students after participation in a citizen science project. There was a weak significant negative correlation between the two variables, r (73) = -0.62, (p<0.05). This trend was observed in 79% of my data. The mean class score for self-determination pre-was 13.71 and increased to 14.13 post compared to the mean pre-score of 16.99 that decreased to 16.93 for career motivation. On average, when students were highly motivated by self-determination they tended to be less motivated by careers (Figure 14).

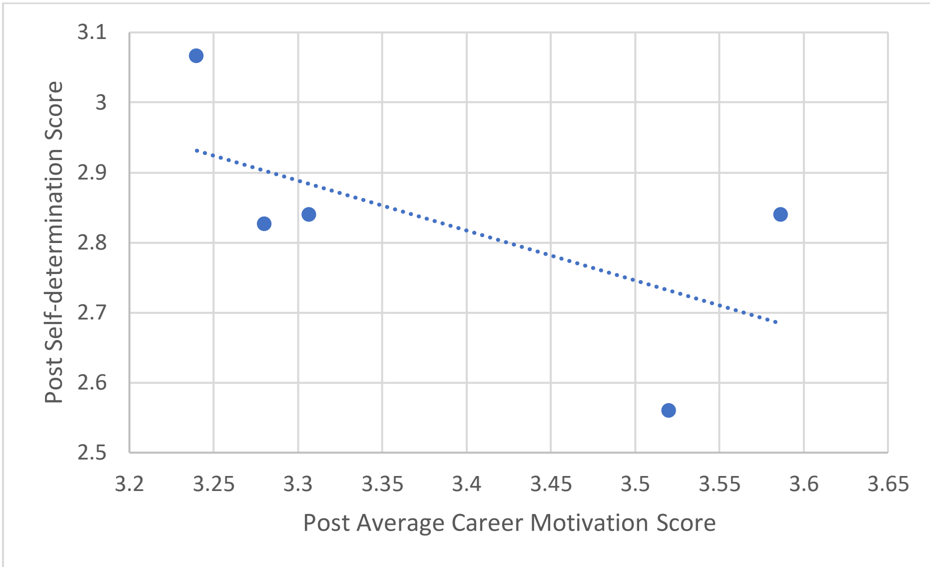

Figure 14. Weak negative correlation between student self-determination and career motivation mean class score post treatment, (*N*=75).

No other positive or negative correlations were determined between mean component scores.

<u>Positive Attitude Toward Scientific Literacy Survey</u>

With regard to my third sub-question, does citizen science participation have any effect on scientific literacy? It was shown that scientific literacy mean class score components were higher post-application than pre-application except for question two and seven. Students on average reported an increase in their enjoyment reading about science and expressing their ideas in writing. There was an encouraging trend observed with students being less bored when offered something interesting to read. In addition to enjoying writing more students were able to see the content differently after. The study increased student scientific literacy levels and strongly suggested improved attitudes toward science reading (Figure 15).

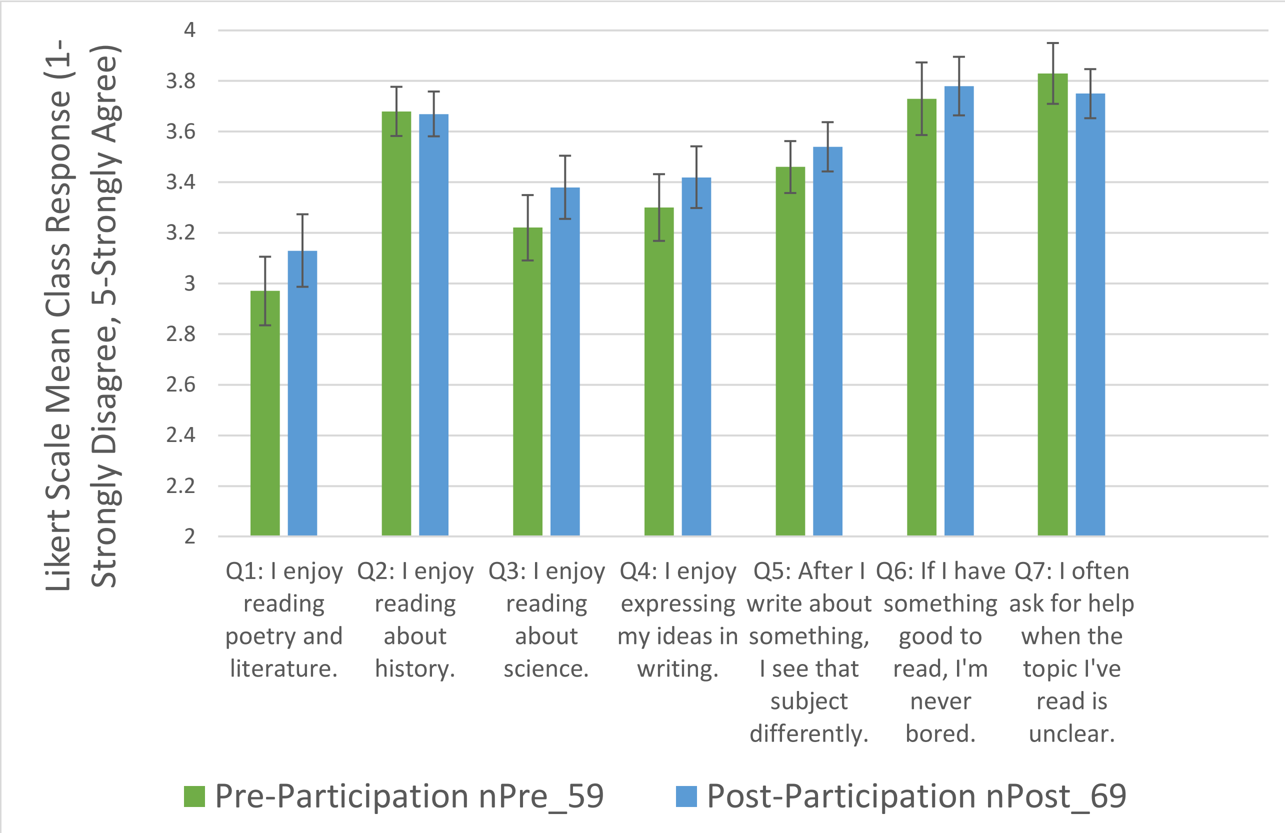

Figure 15. Positive attitude toward literacy survey: pre and post participation in citizen science, (*n*Pre=59, *n*Post=69).

Opinion on Science and Technology Survey

Scientific literacy involves the capability to use scientific knowledge and thought for personal and societal objectives. Accordingly, an increase in the level of scientific literacy serves social objectives. Mean analysis produced an increased agreement by students for the question, "School science has shown me the importance of science for our way of life." Also, students responded with a significant positive change with respect to how much scientific results should be trusted. The integration of citizen science participation produced a favorable opinion and valuation of science and technology (Figure 16).

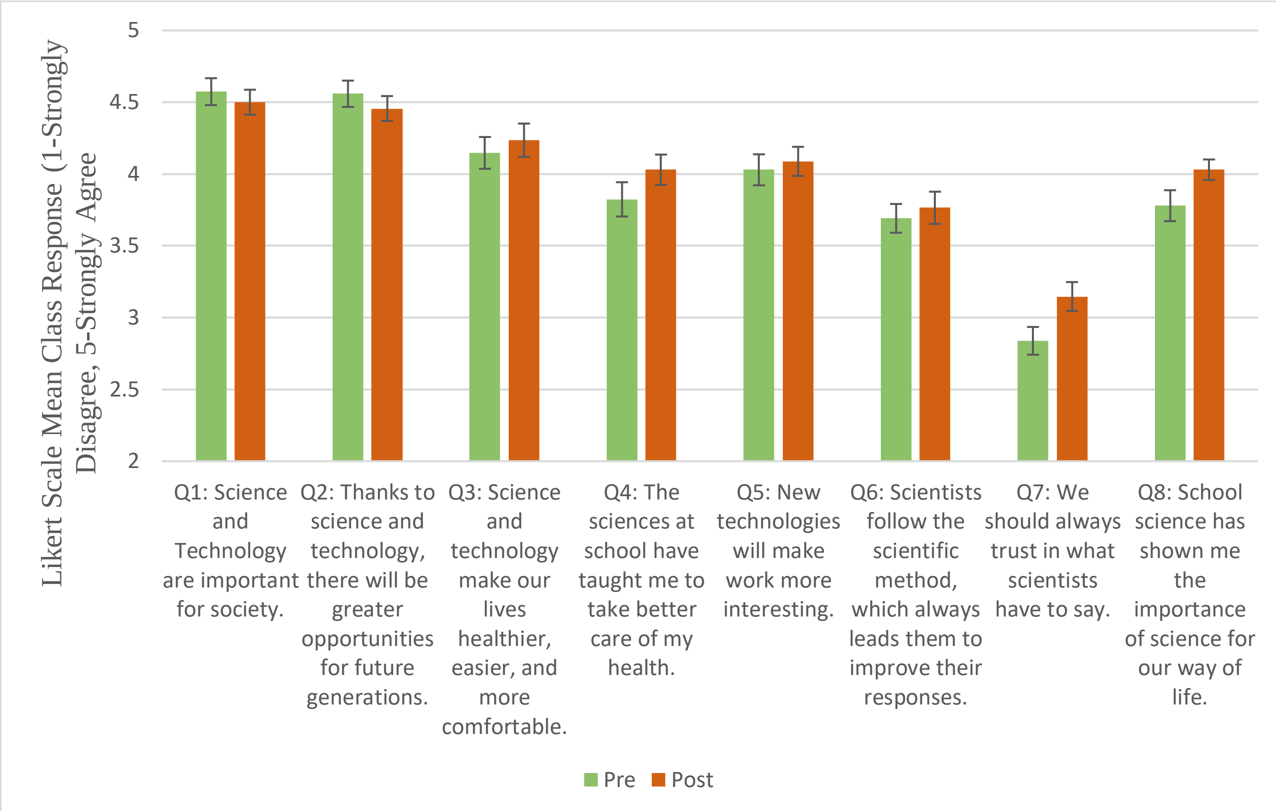

Figure 16. Opinion on science and technology survey: pre and post participation in citizen science, (*N*=68).

Student Remote Learning Survey

Students were randomly selected and self-reported on their individual level of comfort and ease of use regarding online instruction and supportive media. A total of eight questions asked students to rank the most appropriate response and three additional open-ended questions regarding current experience with remote learning. Overwhelmingly, students reported favorably about their experience with remote learning. They felt OCC had gone above their expectations to deliver content, support their needs, and provide online resources during this unprecedented time. The one thing almost all students had in common was missing human interaction. This theme has come up multiple times in discussions and in other surveys (Table

5). Many students also suggested an increase in struggles learning from home. One student commented, “I feel like it's harder to motivate myself when it's online.”

Table 5. Percent of students in agreement with statements pertaining to remote learning, (*n*=21).

Questions	Number of Respondents	Percentage
Q1: How comfortable are you with doing schoolwork remotely?		
Extremely comfortable	7	33.3%
Quite comfortable	10	47.6%
Somewhat comfortable	3	14.2%
Not comfortable at all	1	4.76%
Q2: How easy is it for you to use the remote learning tools like Blackboard, Connect, MasteringBiology etc.?		
Extremely easy	7	33.3%
Quite easy	11	52.3%
Somewhat easy	2	9.52%
Slightly easy	1	4.76%
Q3: In the past week, how easy was it to stay focused long enough to complete your assignments and study at home?		
Extremely easy	1	4.76%
Quite easy	5	23.8%
Somewhat easy	11	52.3%
Slightly easy	3	14.2%
Not easy at all	1	4.76%
Q4: Tell us about how you have engaged in remote learning. In the last week, you have (select all that apply)		
1-2 online activities or supplemental resources	7	33.3%
3-4 online activities or supplemental resources	6	28.6%
5-6 online activities or supplemental resources	6	28.6%

Table 5 continued.

Questions	Number of Respondents	Percentage
7 or more online activities or supplemental resources	2	9.5%
Q5: On average, how much of your day do you spend learning or completing schoolwork?		
1-2 hrs	7	33.3%
2-3 hrs	7	33.3%
4-5 hrs	4	19.0%
5 or more hrs	3	14.2%
Q6: Please tell us how much you agree with the following statement: I am learning new things even while at home.		
Strongly agree	10	47.6%
Agree	10	47.6%
Disagree	1	4.76%
Q7: How much are you learning during remote learning compared to traditional face-to-face instruction?		
Learning much more	1	4.76%
Learning more	2	9.52%
Learning about the same	13	61.9%
Learning somewhat less	5	23.8%
Q8: Fill in the blank with yes or no. \n___________ I have access to a computer or device (other than a smartphone) that I use to complete my school work.		
Yes	21	100%
No	0	0%

Civic Awareness, Engagement, and Perception Survey

Students were shown fifteen images that ranged from young children, middle-aged children, teenagers, young adults, adults, and elderly individuals representing communities within diverse cultures. Students were asked to either agree or disagree with each image as being someone considered a scientist (Figure 17).

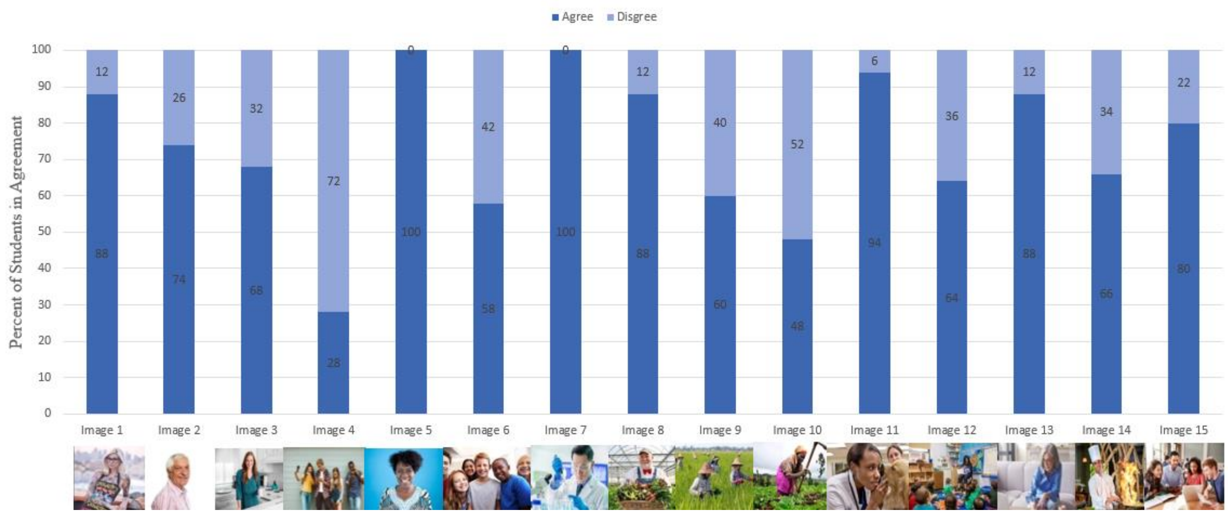

Figure 17. Misconception probe: percent student response in agreement to images of scientists, (*N*=50).

Primary and secondary school aged children received the lowest percentage of agreement. A medical career, like a recognizable veterinarian, received 94% agreement from students. 100% of the class identified a mature black woman as capable of being a scientist along with an Asian male researcher wearing a lab coat holding what appeared to be scientific instruments. Elderly white professors both male and female received high levels of agreement as well. Surprisingly, middle school aged children received one of the lowest scores. This led me to discuss several of the framework examples with students and share the success of young adults in contributing to valid research around the world. Students also recognized after discussion that scientists may look differently and work in diverse environments around the world. This provided the perfect opportunity to discuss and reflect what a scientist meant and how we formed these preconceived notions regarding antiquated beliefs.

<u>WebQuest: Group Inquiry Project Evaluation</u>

Students were at first uncomfortable taking the lead in figuring out the problem and navigating the research to arrive at an appropriate recommendation. Student expectations were based off traditional exercises that required them to take a linear path of steps neatly outlined in exercise procedures. Once students realized that they had choice and could determine their own path from their readings they began to bounce ideas off each other and seek feedback from peers. Students were heard speaking excitedly when they discovered new information and were open to suggestions offered by peers. When students couldn't answer another student's questions, they took initiative to explore more articles and find the answer. Successful completion of the activity required everyone to contribute and assume the role taken. Several student comments from structured reflection after the WebQuest focused on the group dynamic, such as "The interaction with fellow classmates was a nice change of pace. Also, it allowed us to get to know some of our classmates and get involved in what we were trying to accomplish with the experiment." Another student indicated that the ideas presented allowed them to adapt and change their recommendation based off new evidence, "I enjoyed the group inquiry project. My partner did a great job with her research and together our ideas flowed wonderfully. We both shared opinions and even made changes when ideas came along that were better." Multiple groups commented that the activity was more interesting because it used a relevant and real example, "I really liked having to look up real life problems. It really helped me to learn about the problem and what is/ can be done to help prevent it." As a result, the research performed by students in an online group promoted an increase in their inquiry skills through discussion, research, and exchange of views (Figure 18).

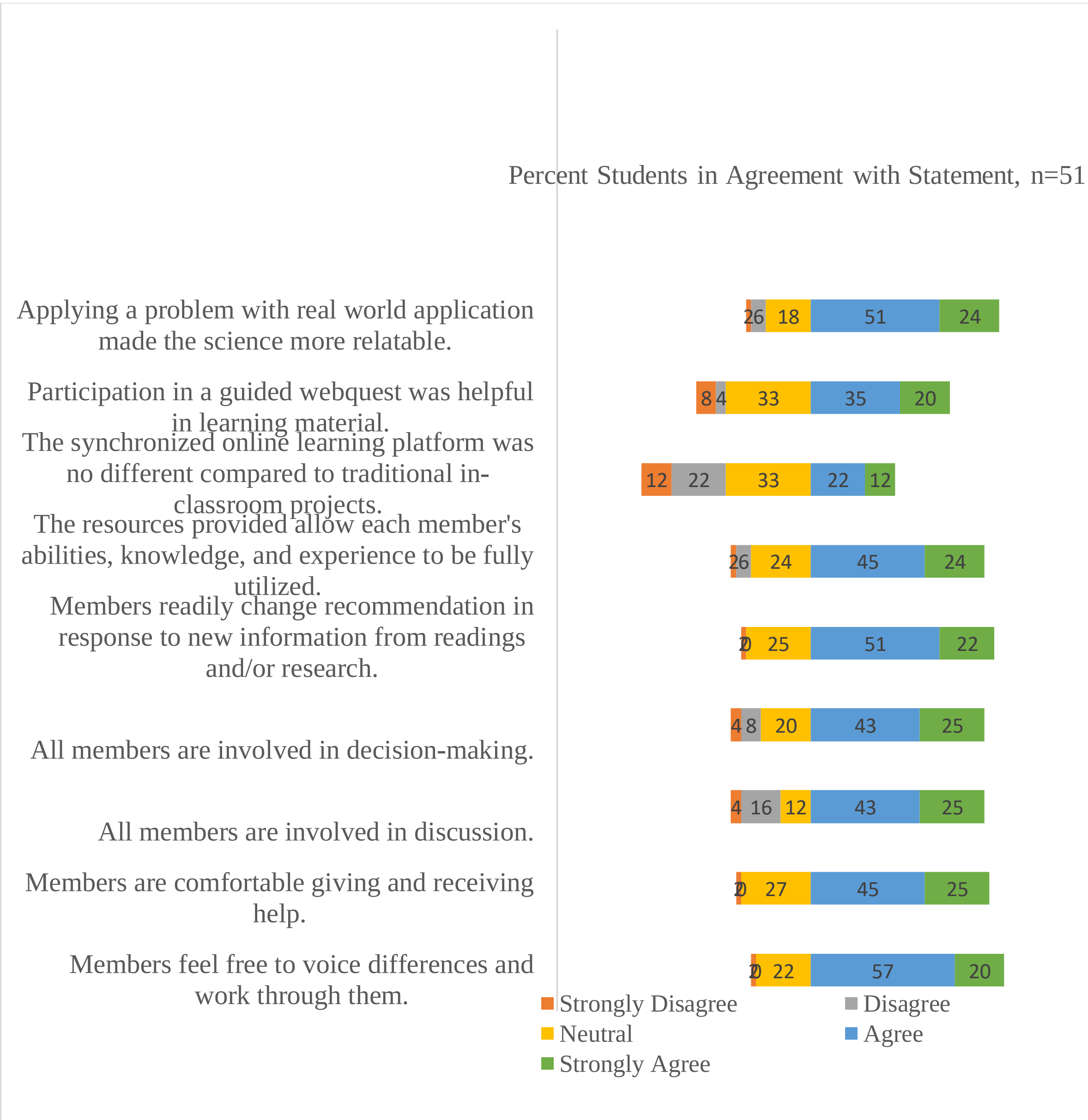

Figure 18. WebQuest: the microbes within group inquiry project evaluation. Percent students in agreement, (*N*=51).

Science Identity Survey Results

The percentage of students that identified as role models for young students pursuing STEM careers was 66% of the sample. Confidence in their ability to conduct authentic science was high at 85%. I was a little disappointed and surprised that only 50% of the students would be considered a “science person” by friends given that all my students were enrolled in a pathway to an allied health science career. Several open-ended questions were given for thematic analysis (Appendix J). With regards to a sense of belonging in science, the trend suggested that many students feel they belong in college science courses but not necessarily in a research environment. One student commented,

> Some people think that women, especially young women, cannot be scientist. I think it dates back to the Frankenstein era. You didn't really see any women become scientist. Now, there are so many women scientist in the lab, they may outnumber men!

Another student discussed the level of support they received as influencing their identity,

> Doubt, it's so much easier when you have someone backing you through encouragement and positive affirmations. It's amazing how much we hold ourselves back because of self-doubt and peer doubt, and this is what I think hinders that identity of being a scientist. We are all scientists at some point!

Students are still very much aware of science stereotypes and the challenges students face in regards to developing a science identity. A student response to the question regarding stereotypes and/or challenges that prevent students from identifying as a scientist, “Women are not as encouraged to pursue science because of the stereotype that they are not as good at math as male students, which is not true.” One final student comment,

> One stereotype is that scientists are "nerdy". In different movies, the kid who builds robots and is involved with other science school clubs is always portrayed as a nerdy kid who was most likely raised in the family that had money. When in reality it doesn't matter what you look like or the family you came from, you can be a scientist if you put effort into it.

It was important to address what science identity means and the many different vocations that require applied scientific knowledge. A lot of the conversation raised awareness to the many individuals within our communities that are doing real science every day that impact our lives. I noticed a shift in my students from being apathetic about identity to vocalizing a need for change in perception. Health science majors do want to be seen as smart, capable, and valued in the scientific community (Figure 19).

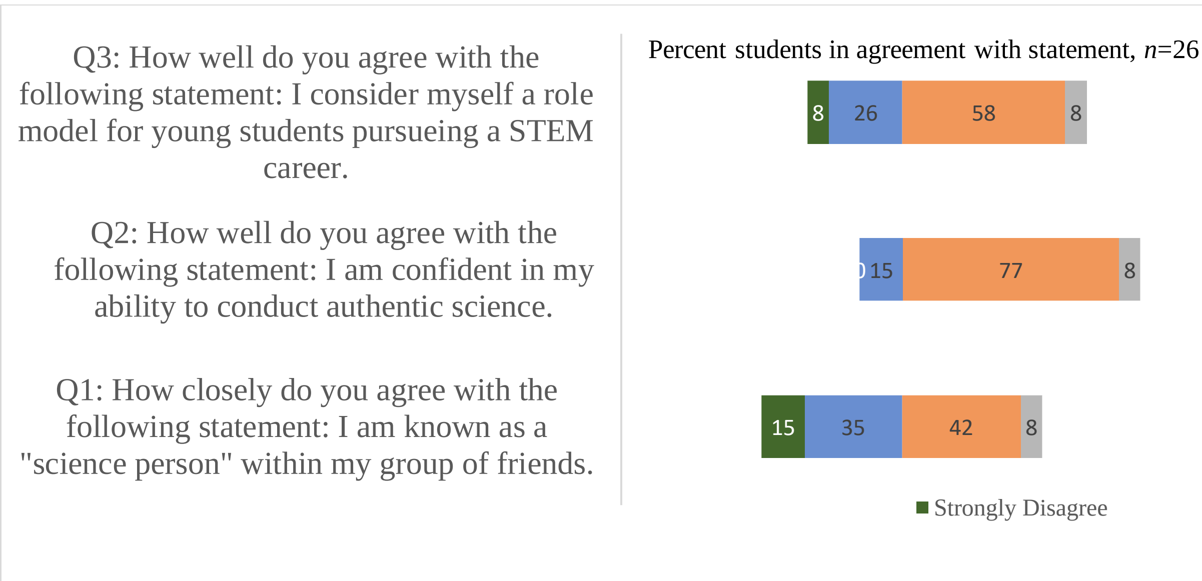

Figure 19. Percent of students in agreement with statements regarding science identity, (*n*=26).

Citizen Science Participation

Upon completion of this activity, students increased their understand that DNA is a diagnostic tool used to discover unseen microbes. They reported having fun in the process and learning better after they performed the lab exercises. All students talked about a desire to do more similar activities. Several students mentioned that it brought their readings to life and made sense out of the complicated protocols not initially understood.

CLAIMS, EVIDENCE, AND REASONING

Participation in citizen science was a positive experience for remote learners that increased their engagement, literacy, and confidence to apply scientific knowledge using real world problems. Citizen science created a unique research experiences during a time of high anxiety and stress caused by the COIVD-19 pandemic. Students were able to engage and collaborate with other online students through hands-on discovery and problem-based learning exercises to share in the whole process of scientific exploration. Projects promoted students taking a more proactive role in their education, increased scientific literacy and interest in the scientific community. Motivational and attitudinal questionnaire results suggested a significant increase in overall intrinsic and self-determination scores.

Claims From the Study

Increase in Student Intrinsic Motivation and Self-Determination

Students took a more proactive role in their education, increased intrinsic motivation, self-identified as “real” scientists, and made positive growth with respect to epistemic beliefs toward science. Intrinsic motivation was previously defined as performing a task or an activity for enjoyment and/or satisfaction, with no external rewards associated with it. Intrinsically motivated students tend to be more eager to learn, more focused, more self-reflective, and self-determined. No extrinsic motivation or grade was given to students for their participation in citizen science. Students upon entering the course had an average score of 13.71 out of 20 on the Likert scale measuring intrinsic motivation. The percentage rose to 13.92 at the end of the project which was a marginal rise but still a positive trend. Self-determination had an initial average score of 13.71 and rose to 14.13 out of 20 which was expected if intrinsic motivation increased as well. There was indeed a strong positive correlation between the two variables of motivation, r(73)=.81, ($p<0.05$). The significance of this finding supports the results from my literature review that suggests students with higher intrinsic motivation on average have increased behaviors related to self-determination. The interest in the topic, content relevancy, and the discovery science nature of citizen science proved to be an effective tool at increasing motivation and self-determination. Student scores for career and grade motivation remained the highest component of motivation for all sections but decreased slightly after participation. This was not surprising as high grades are still prioritized and required for selective admission into health science programs. A decrease in grade motivation was a predicted outcome as students made authentic connections between content and real-world applications that required interest instead of proficiency over topic.

Positive Attitude and Increased Engagement

Students reported being less bored and more engaged to learn about the scientific process. Over 75% of the class agreed with the statement, "Applying a problem with real world application made the science more relatable." There was an encouraging trend observed with students being less bored when offered something they considered interesting to read. They expressed a desire and need for more similar experiences. Students on average reported an increase in their enjoyment reading about science and expressing their ideas in writing. With regard to the level of agreement students enjoyed reading about science, scores went from 3.32 on a 5-point Likert scale to 3.38. In addition to enjoying writing more, students reported an increased ability to see the content differently after. The impact of the study increased student scientific literacy levels and strongly suggested improved attitudes toward science reading. Citizen science can be presented in a variety of reading materials and encourage the amount of time students enjoy critically thinking about what they have written. Projects can highlight favorite subjects, like I did by incorporating historical connections once I knew the majority of the class enjoyed reading about history, to promote a positive attitude about literacy. The beauty of citizen science is that it is highly adaptable to learners. Projects can be tailored to the unique and diverse interests of the students in formal education or public volunteers selected to participate while promoting a more scientifically literate community.

Civic Awareness and Value of Science Increased

The increased interest helped students make connections beyond the classroom and focus less on examination or grade motivation. The combined instrument responses suggested that applying a real-world problem added value to the course. A similar finding was reported by Woburn Memorial High School students in Mrs. Wierzbowski's classroom. A student stated,

> The *Wolbachia* labs helped me further explore my interest in biological science. I found this subject particularly interesting because it was something I had no prior knowledge of, despite over half the world's insect population being infected. Another thing I enjoyed about the lab was that collecting our own bugs personalized it and made it more interesting. Collecting them was rewarding because it had a purpose, and it helped me get over my fear of bugs a little bit. This was my first time doing a lab experiment where I had to 1) sterilize my workspace, 2) wear gloves and goggles, and 3) work over the span of several days.

Another student remarked,

> I especially enjoyed learning about how *Wolbachia* can be used to suppress the population of mosquitoes due to the nuances of how it works (population replacement through the release of *Wolbachia*-infected mosquitoes, and population suppression through the release of male *Wolbachia*-infected mosquitoes).

Testimonial from teachers across the country support the inclusion of this citizen science project and the positive impact observed on student learning. One teacher said,

> Thank you again for taking time to speak to our students last week about the Wolbachia Project. When you disconnected from the Zoom call, students erupted in a round of applause and were *very* chatty about how excited they were to begin this project.

A second teacher stated, "3 of my formers students that were involved have gone on to work on Masters and PhD's related to that kind of science. My point is that this program is effective in engaging students and I would love to assist in seeing it continue in that direction." A former student now teacher had this to say about her experience,

> In college we participated in the *Wolbachia* Project and participating in that research opportunity really made an impact. Now that I am a High School Biology teacher and will be teaching AP Biology next school year the thought of bringing this opportunity to my high school students is very exciting. It is definitely something I would like to bring to my students.

The project has demonstrated the potential to reach students at every educational level and background to promote interest in authentic research. The level of agreement on average among students rose from 3.78 to 4.03 on a 5-point scale to the following Likert item, "School science has shown me the importance of science for our way of life." Students also made significant growth in their trust of the scientific process and what scientists have to say from 2.84 to 3.15 on a 5-point Likert scale. Our students can identify as scientists, take ownership in the process of science, and raise awareness within their communities when citizen science is integrated into their educational experience.

Student Science Identity and Sense of Belonging Increased

Student perception was that an associate degree or obtaining a career as a health professional did not qualify them as a scientist. Toward the end of the course, student beliefs were challenged regarding their sense of belonging and science identity. The percentage of students that identified as role models for young students pursuing STEM careers was 66% of the sample. Confidence in their ability to conduct authentic science was high at 85% toward the end of the course. A misconception probe generated conversation regarding antiquated stereotypes regarding who was capable of conducting science. This approach allowed me to address and redefine what science identity means. Partnering with The *Wolbachia* Project allowed students to see women in research and the collaborations with other marginalized groups from all over the world that were contributing valuable data. Citizen science was a unique way that allowed inclusive and equitable access for all my students desiring to engage in project-based learning.

Value of the Study and Consideration for Future Research

Citizen science had a positive impact on student motivation to learn science and increased my students' awareness regarding the process and impact of scientific research. Students' reported an increased sense of belonging and gained confidence through online breakout discussions with other students while working to solve problems or when collected data was analyzed. Online instruction can leave students feeling disengaged and alienated which decreases intrinsic motivation and negatively impacts scientific literacy. Providing students with opportunities to interact "face to face" during remote instruction helped establish a strong peer support network and on average better attitudes toward learning. I was surprised how willing and excited students were to share their digital images from collecting arthropod samples.

Students were very comfortable with editing pictures and posting to forums to discuss their findings similar to experiences students reported with social media. This was a great time to connect with students on what relevant material needed to be reported and included regarding samples in a non-threatening or intimidating method. Students were allowed the freedom of choice regarding where and when samples were collected which encouraged participation. Covid-19 was still a very serious health threat and many students were scared to come to campus. There were no negative impacts or perceived effect on grade used to motivate students. Students wanted to learn more and enjoyed the social interaction. The integration of a citizen science experience and partnering with real scientists allowed my students to think bigger than themselves and challenge traditional definitions of scientific inquiry. Students even surprised themselves in how much they enjoyed the experience and were heard commenting to each other that it was actually fun. Students took the lead and were eager to see what other students found compared to their own efforts.

The most meaningful part of this study from my perspective were the unintentional conversations that took place regarding misconceptions and stereotypes of scientists. My initial sub-goal was to acknowledge, identify, and address any gender or age bias toward student perceptions of individuals viewed as scientists. The survey results on average indicated that students initially valued science but didn’t consider careers in health science as valid science identities. I was surprised by how many students didn’t think their degree from a community college or a career in healthcare qualified them as a scientist. The use of student quotes as a misconception probe allowed for open dialogue and conversation regarding why on average students believed a certain stereotype. I particularly enjoyed these discussions and was impressed by the honesty of student responses. The students were able to engage in respectful discussions and find supporting evidence that challenged these views. The overall process revealed a need to broaden the definition of scientist and how science is conducted. At the end, students gained a new perspective that celebrated the value of science conducted by everyone.

Impact of Action Research on the Author

In this study I hoped to demonstrate that citizen science is a valid option to meet the growing demand for more inclusive and equitable access to authentic project-based learning particularly during the rapid transition to remote instruction. That regardless of age, gender, socioeconomic class and technological skills, anyone can make meaningful connections and contributions that improve our understanding of the nature of science. I was initially worried how student motivation would be impacted by removing access to in-person instruction and traditional hands-on investigations. Microbiology is a difficult course and allied health science students are under a tremendous pressure to get a good grade allowing admittance into a competitive program. In the past, grade motivation was the dominant component for students which negatively impacted intrinsic motivation, cooperative learning, and critical thinking. Students cared more about their score then making relevant connections or applying new knowledge. I wanted to ease some of that grade anxiety while maintaining the rigor of the course and improve student attitudes.
After this experience, I feel even more passionately about getting students to make relevant connections to their community and raise awareness about scientific research. When students care or take an interest in the topic they tend to put forth more effort to learn. I plan moving forward to include more qualitative instruments to identify their concerns or questions. My curriculum will benefit from including local relevant problems that inspire them to seek answers

through discovery science that impact their daily life or community. The change in student perspective from I can't do science to I am a science role model capable of contributing data was a turning point in my career. This experience has made me analyze and evaluate my role in every student's educational journey. I have had to step out of my comfort zone and embrace the role of facilitator in order to promote active learning during synchronous instruction. I realize now more than ever the role educators have in helping students form mature perception of science.

If I was to conduct this study again, I would incorporate earlier more collaborations in breakout rooms online. Promoting a sense of belonging and boosting confidence through real-time discussions at the start of the semester I feel would have increased motivation further and identified potential areas of concern regarding science identity. I also would include recorded videos of student data collection methods and student testimonials to show in class for students to watch. I feel if students can relate to and see science in action conducted by someone who looks, talks, and has similar goals a positive impact on epistemic beliefs would take place. The last thing I would change would be the timing of the citizen science participation. The project fell on the same dates students were taking final exams and were experiencing increased stress, anxiety, and less free time. To facilitate and improve participation I'd move the activity up one week. I would also consider doing structured interviews if time permitted in any future projects in order to obtain more quantitative data. Overall, I am pleased with the level of engagement and improved motivation I saw in my students. I feel there is a ton of potential to improve upon the design and implementation so other courses may benefit from similar projects. Integrating this project into my synchronous classroom has allowed me to see how I can incorporate a meaningful experience online, promote awareness and partnership within the community the college strives to serve.

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APPENDICES

APPENDIX A

INSTITUTIONAL REVIEW BOARD EXEMPTION

Move to Categorize Snooze Undo ···

[External] RE: Andrews IRB Exemption Application (MSSE)

2

Label: OCC 3 Year Delete (3 years) Expires: Thu 11/7/2024 2:05 PM

BK Beiswanger, Kelly <kelly.beiswanger@montana.edu>
Mon 11/8/2021 2:05 PM
To: April M. Andrews
Cc: Reuer, Marcie <marcie.reuer@montana.edu>

Andrews-Reuer AA11082...
803 KB

You don't often get email from kelly.beiswanger@montana.edu. Learn why this is important

Dear April,

Thank you for your application. This email acknowledges receipt of the request for IRB Review and serves as the Approval Letter for your research. Your new **IRB Exempt Protocol # is AA110821-EX**.

Study Title: **How does participation in citizen science influence microbiology students' critical thinking skills, environmental engagement and application of science to real world problems?**

As the PI, it is your responsibility to facilitate subject understanding by informing subjects of all aspects of the project, providing an opportunity to ask questions, and describing risks and benefits of participation. Submit any new changes to the research protocol to the IRB via Amendment Form prior to implementing.

The research described in your submission is exempt from the requirement of additional review by the Institutional Review Board in accordance with 45 CFR 690.104(d). The specific paragraph which applies to your research is:

(1) Research, conducted in established or commonly accepted educational settings, that specifically involves normal educational practices that are not likely to adversely impact students' opportunity to learn required educational content or the assessment of educators who provide instruction. This includes most research on regular and special education instructional strategies, and research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

Thank you,
Kelly Beiswanger

IRB Administrator & Program Manager
Office of Research Compliance
Hamilton Hall 114
Montana State University
kelly.beiswanger@montana.edu
406-994-4706
https://www.montana.edu/orc/irb

APPENDIX B

SCIENCE MOTIVATION QUESTIONNAIRE (SMQ-II)

Science Motivation Questionnaire II (SMQ-II)

In order to better understand what you think and how you feel about your science courses, please respond to each of the following statements from the perspective of "When I am in a science course..." Please take a moment to think and answer honestly. This survey is anonymous and no identifier is given to link you to your response. Thank you for your voluntary participation and consent to be part of this research.

Statements	Never 0	Rarely 1	Sometimes 2	Often 3	Always 4
Q1. The science I learn is relevant to my life.					
Q2. I like to do better than other students on science tests.					
Q3. Learning science is interesting					
Q4. Getting a good science grade is important to me.					
Q5. I put enough effort into learning science.					
Q6. I use strategies to learn science well.					
Q7. Learning science will help me get a good job.					
Q8. It is important that I get an "A" in science.					
Q9. I am confident I will do well on science tests.					
Q10. Knowing science will give me a career advantage.					
Q11. I spend a lot of time learning science.					
Q12. Learning science makes my life more meaningful.					
Q13. Understanding science will benefit my career.					
Q14. I am confident I will do well on science labs and projects.					
Q15. I believe I can master science knowledge and skills.					
Q16. I prepare well for science tests and labs.					
Q17. I am curious about discoveries in science.					
Q18. I believe I can earn a grade of "A" in science.					
Q19. I enjoy learning science.					
Q20. I think about the grade I will get in science.					
Q21. I am sure I can understand science.					
Q22. I study hard to learn science.					
Q23. My career will involve science.					
Q24. Scoring high on science tests and labs matters to me.					
Q25. I will use science problem-solving skills in my career.					

APPENDIX C

POSITIVE ATTITUDE TOWARD SCIENTIFIC LITERACY

Positive Attitude Toward Literacy Survey

Select the number that indicates the extent to which you agree/disagree with each of the following statements about your views or perspective in general. There is neither a right or wrong answer to any question. Remember, your identity and responses are anonymous and no personal identifier will be attached to your survey. Thank you for taking the time to voluntarily complete this survey.

Statements	Strongly Agree	Disagree	Neutral	Agree	Strongly Agree
Q1. I enjoy reading poetry and literature.	1	2	3	4	5
Q2. I enjoy reading about history.	1	2	3	4	5
Q3. I enjoy reading about science.	1	2	3	4	5
Q4. I enjoy expressing my ideas in writing.	1	2	3	4	5
Q5. After I write about something, I see that subject differently.	1	2	3	4	5
Q6. If I have something good to read, I'm never bored.	1	2	3	4	5
Q7. I often ask for help when the topic I've read is unclear.	1	2	3	4	5

Source: Adapted with permission from Positive Attitude Toward Literacy Scale (PATL) Center of Inquiry in the Liberal Arts at Wabash College https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.353.2718&rep=rep1&type=pdf

APPENDIX D

OPINION ON SCIENCE AND TECHNOLOGY

Opinion on Science and Technology Survey

Indicate how much you agree with the following statements, from 1: I disagree very much, to 5: I agree a lot. Remember, the survey is voluntary and the results are anonymous. No personal identifier will be used with your voluntary participation.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Q1. Science and Technology are important for society.	1	2	3	4	5
Q2. Thanks to science and technology, there will be greater opportunities for future generations.	1	2	3	4	5
Q3. Science and technology make our lives healthier, easier, and more comfortable.	1	2	3	4	5
Q4. The sciences at school have taught me to take better care of my health.	1	2	3	4	5
Q5. New technologies will make work more interesting.	1	2	3	4	5
Q6. Scientists follow the scientific method, which always leads them to improve their responses.	1	2	3	4	5
Q7. We should always trust in what scientists have to say.	1	2	3	4	5
Q8. School science has shown me the importance of science for our way of life.	1	2	3	4	5

Source: Adapted with permission. https://www.mdpi.com/724194

APPENDIX E

STUDENT REMOTE LEARNING SURVEY

Student Remote Learning Survey

To better support you, please answer the following questions about how you think and feel, especially while learning remotely. Please respond honestly- there are no right or wrong answers. Your voice is important, so thank you for sharing your thoughts and experience so far. Results remain anonymous and no personal identifier is used.

1. How comfortable are you with doing schoolwork remotely?

    1. Not comfortable at all
    2. Slightly comfortable
    3. Somewhat comfortable
    4. Quite comfortable
    5. Extremely comfortable

2. How easy is it for you to use the remote learning tools like Blackboard, Connect, MasteringBiology etc.?

    1. Not easy at all
    2. Slightly easy
    3. Somewhat easy
    4. Quite easy
    5. Extremely easy

3. In the past week, how easy was it to stay focused long enough to complete your assignments and study at home?

    1. Not easy at all
    2. Slightly easy
    3. Somewhat easy
    4. Quite easy
    5. Extremely easy

4. Tell us about how you have engaged in remote learning. In the last week, you have (select all that apply)

    1. Joined a Blackboard Collaborate session with your class
    2. Joined a video call for one-on-one instruction and/or support with your teacher
    3. Participated in an online discussion board
    4. Read a book
    5. Created a project or art
    6. Watched a cultural event online or supplemental video shared by instructor
    7. Participated in an online tutorial or virtual lab activity

5. On average, how much of your day do you spend learning or completing schoolwork?

1.Less than an hour
2. 1-2 hours
3. 2-3 hours
4. 4-5 hours
5. 5 or more hours

6. Please tell us how much you agree with the following statement: I am learning new things even while at home

    1. Strongly agree
    2. Disagree
    3. Agree
    4. Strongly Agree

7. How much are you learning during remote learning compared to traditional face-to-face instruction?

    1. Learning much less
    2. Learning somewhat less
    3. Learning about the same
    4. Learning more
    5. Learning much more

8. Fill in the blank with yes or no.

_______________ I have access to a computer or device (other than a smartphone) that I use to complete my school work.

9. Please describe one thing your teacher has done in your remote learning that has motivated you or you found engaging.

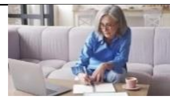
10. What if anything do you feel is a negative or miss with learning remotely?

11. What else could your school do to help or support you with remote learning during the COVID-19 pandemic?

APPENDIX F

CIVIC AWARENESS AND ENGAGEMENT

	Image	Agree	Percent	Disagree	Percent
Q1					
Q2					
Q3					
Q4					
Q5					
Q6					
Q7					
Q8					
Q9					
Q10					

Q11					
Q12					
Q13					
Q14					
Q15					

APPENDIX G

WEBQUEST ONLINE INTRODUCTION: THE MICROBES WITHIN

WEBQUEST ONLINE INTRODUCTION: The Microbes Within

A WebQuest exploring the effects of endosymbiosis on reproduction, evolution and human health. Students will work in groups of 3 to solve a medical mystery and help prevent the next great epidemic. Students will demonstrate comprehension of fundamental biology concepts, host-microbe interactions, and critically think about the implications this research could have on preventing the spread of illnesses all over the world. Students must work collaboratively to support and defend their position using CER. Students will submit a short paragraph to the appropriate Discussion Board thread on Blackboard that summarizes their combined research and recommendation. Students will work in Collaborate break out rooms instead of in-person due to the institution's current pandemic policy.

Link:
https://serc.carleton.edu/microbelife/k12/microbes_within/introduction.html

Homepage Screenshot:

APPENDIX H

THE MICROBES WITHIN: WEBQUEST INQUIRY ONLINE EVALUATION

Blackboard Collaborate Group Inquiry Project Evaluation

Now that we have finished our group inquiry project, it's time to evaluate. Individually, reflect on your group's dynamics and anonymously rate them according to each of the following variables based on your level of agreement with each statement. There are some specific questions that apply to your level of participation and engagement. Results will continue to be anonymous and no personal identifier used.

Statements	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Q1. Goals are clear, understood, and have the full commitment of team members.	1	2	3	4	5
Q2. Members express thoughts, feelings, and ideas freely.	1	2	3	4	5
Q3. Members trust one another and do not fear ridicule or reprisal	1	2	3	4	5
Q4. Members feel free to voice differences and work through them.	1	2	3	4	5
Q5. Members are comfortable giving and receiving help.	1	2	3	4	5
Q6. All members are involved in discussion.	1	2	3	4	5
Q7. All members are involved in decision-making.	1	2	3	4	5
Q8. Members readily change recommendation in response to new information from readings and/or research.	1	2	3	4	5
Q9. The resources provided allow each member's abilities, knowledge, and experience to be fully utilized.	1	2	3	4	5
Q10. The synchronized online learning platform was no different compared to traditional in-classroom projects.	1	2	3	4	5
Q11. Participation in a guided WebQuest was helpful in learning new material.	1	2	3	4	5
Q12. Applying a problem with real world application made the science more relatable.	1	2	3	4	5

Q13. This area is intentionally left blank to allow for written response. Please provide any additional feedback, both positive and negative, regarding the inquiry project.

APPENDIX I

SAMPLES OF STUDENT WEBQUEST WRITTEN RECOMMENDATIONS

Samples from student group discussion board posts across all sections from WebQuest:

"To protect against public health, our group decided to educate the community. We will be introducing a plan of ideas to communicate on how to control the insect population in and around their homes. One of the main solutions would be to remove any standing water around the community. This standing water attracts the mosquitoes in which they proceed to lay their eggs. We would remove standing water by re-grading yards and land. Another solution would be to introduce a safe repellent to spray against the mosquitoes. Killing off the infected mosquitoes would discontinue the continuing spread of *Wolbachia*."

"In the reproductive stand point, *Wolbachia* is one of many bacteria that can infect its host and essentially kill only one sex. Wolbachia alters the sperm of the male host so it can only breed with an infected female, this makes it so the population of the mosquitos is a vast majority of infected females. Our first approach could be to genetically engineer some type of a strain to send out into the infected area to alter the genes of the males making the infected female population drastically decrease. From a microbiology view, the disease is transmitted through mosquito bites so we need to stop the initial transmission from occurring. This can be done in a number of ways such as those on the island wearing bug spray, wearing long clothing that does not cling to the skin, and avoiding high areas of exposure where a large population of the infected species lives. Lastly, looking at the disease itself, the drug, Doxycycline has been proven to stop the infection before it takes hold. So, one solution for this could be using Doxycycline as somewhat of a "probiotic" and those who are around the area, traveling, or have been around those exposed can take this as a preventative measure."

"*Wolbachia* is a parasite that lives inside a variety of insects. These infected insects reproduce to increase the number of female offspring and suppress or eliminate males. Mutations in the sex lethal gene kill one sex or the other. *Wolbachia* is associated with human diseases such as onchocerciasis (river blindness) and lymphatic filariasis (elephantiasis). River blindness can cause serious visual impairments, as well as intense itching, rashes, and lesions. Currently, river blindness is managed by using chemicals to stop adult worms from reproducing and insecticides to kill the flies that carry worms. Gathering a group of insects and infecting them with antibiotic tetracycline would kill Wolbachia causing them to become sterile. This will slowly eliminate the spread of *Wolbachia*. We also recommend further research on developing a vaccine for the human host or a medication for the disease itself rather than focusing on the flies. Gene sequencing is a great method to investigate the parasite's interaction with the host and will make great strides in developing a vaccine."

"My group and I think that capturing female misquotes with *Wolbachia* and having them reproduce, while only letting out the males could contain the problem. The males do not harm humans or animals. When a male with Wolbachia mates with a female without *Wolbachia* they eggs are not hatched therefore the population would decline. Male mosquitoes do not bite they survive by sucking on nectar flowers. The males would be released by professionals. The females on the other hand would stay in the factory being observed by scientists and their job would only to be reproduction. Another way we could contain *Wolbachia* is eliminating standing water where misquotes lay their eggs. This would eliminate somewhere the females could lay their eggs. Therefore, a decline in newly born mosquitoes."

APPENDIX J

SCIENCE IDENTITY SURVEY

What's Your Science Identity?

The semester is half over and we ask you to reflect on your science identity. Answer the following questions based off of your current perception and exposure to various scientific experiences this year.

1. How closely do you agree with the following statement: I am known as the "science person" within my group of friends?

    1. Strongly Disagree
    2. Disagree
    3. Agree
    4. Strongly Agree

2. Do you feel a sense of belonging in science? Explain reasoning.

3. Do you consider yourself to be a scientist? Why or why not.

4. How well do you agree with the following statement: I am confident in my ability to conduct authentic science?

    1. Strongly Disagree
    2. Disagree
    3. Agree
    4. Strongly Agree

5. How well do you agree with the following statement: I consider myself a role model for young students pursuing a STEM career?

    1. Strongly Disagree
    2. Disagree
    3. Agree
    4. Strongly Agree

6. What stereotypes and/or challenges do you think exist that prevent students from identifying as a scientist?

APPENDIX K

ONLINE STUDENT RESOURCE: VOLUNTARY PARTICIPATION IN CITIZEN SCIENCE: THE *WOLBACHIA* PROJECT

Voluntary Participation in Citizen Science: The *Wolbachia* Project

The *Wolbachia* Project is organized as a five-part lab series that I will modify into a one-day workshop. Each "Project Guide" has been designed to facilitate inquiry-based research experiences and optimize student success in the classroom. The intro guide (project background) will be given online ahead and discussed to facilitate comprehension during lab activities.

Project Guidelines: https://www.vanderbilt.edu/wolbachiaproject/lab-series/

Project Guideline Screenshot:

Students registered in the synchronous online lecture will have the chance to conduct field work, gather samples, work in groups to analyze data, and learn molecular techniques in an optional workshop day held on campus. Students will create free online accounts to record, upload digital images, and contribute to a large national database made possible through a partnership with Vanderbilt University. Students unable to attend in person will still participate through a live streaming of activities. The objective is to determine if and what percent of local arthropod samples collected are positive for *Wolbachia*. The students will work collaboratively to write a paper detailing their findings to submit for publication.

Link: https://www.vanderbilt.edu/wolbachiaproject/

APPENDIX L

OWENS COMMUNITY COLLEGE VIDEO AND PHOTO RELEASE

OWENS
COMMUNITY COLLEGE

OWENS STATE COMMUNITY COLLEGE
Photography/ Video Release

Project: ____

Name of Student Completing Project: ______________________________

For valuable consideration received, I hereby grant to **Owens Community College** and its legal representatives and assigns, the irrevocable and unrestricted right to use and disseminate photographs/video of me, or in which I may be included, for educational/instructional purposes in any other manner and medium; to alter the same without restriction; and to copyright the same if necessary for educational/instructional purposes. I hereby release Owens Community College and its legal representatives and assign from all claims and liability relating to said photographs/video.

Name ____

Signature ____

Date:

Location of Photo/Video: ____________________________________

Address ____

Email address ____

If under 18 years of age, a parent/guardian must sign below:

____