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Evaluating the Impact of Intersecting Research and Outreach Marine Science Programs on Elementary and Undergraduate Students

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EVALUATING THE IMPACT OF INTERSECTING RESEARCH AND OUTREACH MARINE SCIENCE PROGRAMS ON ELEMENTARY AND UNDERGRADUATE STUDENTS

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Master of Science
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ABSTRACT

Climate change is one of the most destructive forces our ocean is currently experiencing. Despite this, many students are not taught the basics of climate change science and ocean literacy in public school systems. My work seeks to combat these deficits through educational experiences in marine science for undergraduate and local elementary students involving three studies incorporating marine-science based research and outreach. The first goal of this study was to understand the role that marine science-based research and outreach played on undergraduate student understanding of climate change/ocean literacy, attitudes towards marine conservation, and career development in STEM. In this study, alumni from both research and outreach marine science programs completed surveys to assess these dependent variables and independent variables (mentorship, length of enrollment, research, or outreach program type). Variables were assessed using multivariate linear regressions, with best fits determined by minimum delta Akaike information criteria (ΔAICc) scores. From this study, I determined that positive mentorship increased knowledge and professional development, length of enrollment enhanced professional development and attitudes, and type of program influenced attitudes. The second goal was to apply and evaluate project-based learning (PBL) in an online, informal marine-science undergraduate course. I administered pre and post surveys to enrolled undergraduates to evaluate changes in student conceptual understanding, attitudes, and skill development. Using paired Wilcoxon-Signed Rank tests, I determined that students conceptual understanding and skill development significantly increased after integration in the PBL curriculum. However, further qualitative analysis needs to be completed to determine if these gains are specific to PBL, or due to simple class enrollment. The final goal was to assess the use of marine-based citizen science in elementary school children. Using 360 videos taken directly from coral reef research sites, elementary students acted as “citizen scientists”, counting fish in VR for a research project in fish behavior. To assess how citizen science impacts elementary student science identity, and conceptual understanding, students were randomly placed in either a citizen science or non-citizen science group. Personal Meaning Map and Draw-A-Scientist assessments were used before and after the program to quantitatively evaluate these dependent variables. From this study, no quantitative changes were seen between pre and post assessments for any of our variables, although student gender and ethnicity were related to the scientists they drew. Future analyses will focus on qualitative components of student assessments. Collectively, these studies show that experiential learning can be an effective way to integrate students into marine science and help them understand the impacts of climate change. However, further research is needed to understand if PBL and citizen science specifically can be used to change student understanding and attitudes.

DEDICATION

I would like to dedicate this thesis to my parents and undergraduate mentor, Kylie Smith.

Mom and Dad, you always support me in any of my pursuits, whether they are personal or professional. Without your help, I could never have completed my master's degree or moved on to pursue my PhD. You have both always been my rocks, the people I call when I feel completely overwhelmed, and the ones that celebrate my successes with me. You have encouraged me even when I felt that I could not succeed and will always be the people I turn to when life gets tough. Thank you both for helping me get through this phase of graduate school and prepare for the next!

Kylie, you were the reason I wanted to know more about the ocean, SCUBA, and undergraduate research. Because of you, I had some of the greatest and most unique experiences as an undergraduate and have dedicated my studies to helping other students have similar opportunities. Even as a graduate student, you helped me navigate many of the difficulties in graduate school and personally. I hope to become as great a mentor as you as I continue in academia and beyond. Thank you for everything you have done for me, I hope this thesis makes you proud!

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First and foremost, I would like to acknowledge the Creative Inquiry program at Clemson University. Almost all this thesis is based around courses funded and promoted by this program. This program also gave me the inspiration for each chapter and research project. Thank you to my lab mate Kea Payton who did so much to help me during my data collection and served as a wonderful mentor, lab mate, and friend. I would also like to acknowledge the undergraduates who helped to make this happen, specifically Cem Geray and Kellie Smith who were vital parts of both Chapters 3 and 4 and two of the greatest students a mentor can work with. Thank you to the other undergraduates in both the Conservation of Marine Resources Creative Inquiry and Something Very Fishy for all your hard work and dedication to this project as well. Additional thanks go to the elementary students and teachers who allowed us to work with them for the work featured in Chapter 5. I would like to acknowledge my advisor Dr. Michael Childress and my committee members Dr. Meghnaa Tallapragada, Dr. Danielle Herro, and Dr. Cindy Lee. You have all been instrumental in this thesis and it could not have happened without you!

Finally, I would like to thank the funding agencies that supported this work: South Carolina SeaGrant, the South Carolina Arts Commission, the Slocum-Lunz foundation, the International Women's Fishing Association, and Clemson's Graduate Student Government.

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CHAPTER ONE
INTRODUCTION

Overview

This thesis aimed to understand the value of using experiential learning to inform two student groups (undergraduate and elementary) on climate change, marine science, and ocean health. Three specific goals were to 1) understand the impact of experiential research and outreach education on undergraduate alumni from a marine science program, 2) assess the benefits of implementing project-based learning for online undergraduates in marine science outreach, and 3) understand the impact of integrating experiential citizen science with elementary students using virtual reality. To accomplish these three goals, I utilized Clemson University's Creative Inquiry program to engage with undergraduates participating in the Conservation of Marine Resources marine science research Creative Inquiry and the Something Very Fishy marine science outreach Creative Inquiry. My research sought to understand the following benefits of both marine science research and outreach for undergraduates and elementary students: 1) changes in confidence in communicating climate change and ocean health issues to others, 2) increases in understanding of marine science concepts related to the seven ocean literacy principles, and 3) increases in overall science identity and self-efficacy related to STEM fields.

Intellectual Merit

This thesis project's academic merit related directly to its ability to enhance student success through experiential learning. These merits included 1) evaluating the costs and benefits of using both outreach and research as experiential learning platforms for climate change, 2) understanding the factors that enhance student science identity, knowledge, attitudes towards societal issues, 3) assessing the effectiveness of project-based learning on undergraduates involved in outreach, and 4) evaluating the benefits of connecting research to outreach through citizen science in elementary schools. Broadly, the results of this thesis have the potential to lead to changes in the connection between research, outreach, and education for different student groups (undergraduate and elementary). Additionally, due to the diversity of students amongst both undergraduate and elementary student groups, these studies engaged students that may not traditionally have had access to these experiences. Through this, I discovered more meaningful ways of enhancing student success and knowledge of divisive scientific topics through proven practice.

Broader Impacts

Climate change research is prolific, and ways to communicate climate change have been evaluated for decades (Corner et al., 2015; Reid, 2019). However, formal approaches to teach climate change are often met with cynicism and combative biases in education (Reid, 2019). In the case of my programs, by using climate change in the context of marine science through both outreach and research, I can move away from these biases and towards scientific principles. The broader impact goals from this study included 1) allowing undergraduate students to act as agents of change for climate change research and outreach, 2) increasing awareness and understanding of climate change impacts on ocean health in undergraduate students, 3) increasing undergraduate self-identity with science, science communication, and STEM education, and 4) informing elementary students on climate change impacts while inspiring them to action. My attempt to combine research and outreach with undergraduate and elementary education allowed for a unique advantage of connecting research to practice through a STEM feedback pipeline (Figure 1.1).

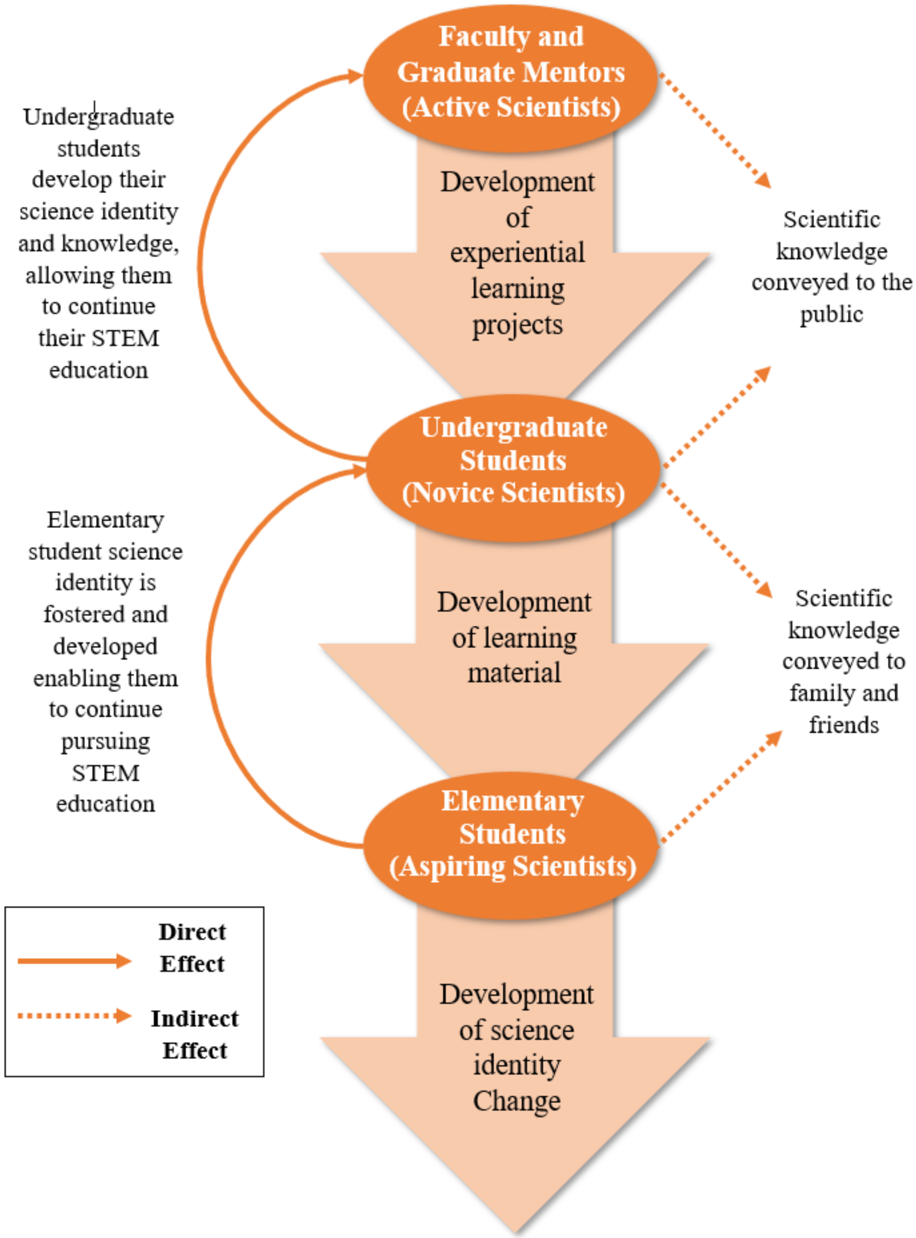

Figure 1.1. STEM feedback flowchart starting at faculty and graduate mentors, moving through undergraduate students towards elementary students. Direct effects of the project are indicated with rounded, solid arrows. Elementary students develop their science identity – encouraging them to pursue STEM education. Undergraduate students develop both their identity and science understanding, allowing them to pursue higher education and STEM careers. Potential, indirect effects of the project are indicated with straight, dotted arrows. Elementary and undergraduate students convey their scientific understanding to their parents. Undergraduate students along with faculty and graduate mentors communicate their science understanding to the public.

Objectives and Research Hypotheses

Objective 1: Understand the impact of experiential research and outreach education on Creative Inquiry undergraduate alumni

- H_1: Alumni who indicate higher satisfaction with their mentors will indicate increases in knowledge and attitudes towards ocean conservation and health alongside a preference towards careers related to science.
- H_2: Alumni who were enrolled for longer periods of time will indicate increases in knowledge and attitudes towards ocean conservation and health alongside a preference towards careers related to science.
- H_3: Alumni enrolled in the research program will indicate increases in knowledge towards ocean conservation, alumni enrolled in the outreach program will indicate an increase in ocean conservation desire, and those enrolled in both will indicate a preference towards careers related to science.

Objective 2: Assess the benefit of implementing project-based learning in an outreach program.

- H_1: Undergraduate students will experience gains in conceptual understanding of basic marine science concepts due to project-based learning.
- H_2: Project-based learning will alter undergraduate student attitudes towards conservation and science.
- H_3: Undergraduates involved in project-based learning will increase their confidence in conducting science communication and science education.

Objective 3: Understand the impact of integrating experiential citizen science with elementary students.

- H_1: Elementary students' gender and ethnicity will influence their perception of marine scientists.
- H_2: Citizen science will alter elementary student science identity and perceptions of a scientist away from that of a traditional scientist and towards a more open view of scientists.
- H_3: Citizen science will increase student understanding of climate change and ocean health and alter their attitudes towards climate change and ocean health.

Project Description

Theoretical Framework: Experiential Learning

The goals of this thesis relate directly to a well-understood theory in education called experiential learning. The theory has been tested in many contexts, from elementary schools to postgraduate education. It has also been used to tackle pervasive societal issues in the classroom. Experiential learning dates to 1938, when John Dewey first proposed that the best way to create impactful learning was by doing (Dewey, 1938). This belief was based on the transaction of learning between students and their environment in which students contribute to their surroundings while their surroundings have internal impacts on them (Kolb, 1984). Dewey proposed that learning occurs through a combination of five phases: suggestions of a course of action, intellectualization through defining a problem, development of a hypothesis, reasoning of the hypothesis through applied knowledge, and testing the hypothesis through experimentation (Figure 1.2) (Giles and Eyler, 1994). The Lewinian Model of Action Research and Laboratory training describes this as cyclic, with feedback mechanisms driving progression in each phase (Kolb, 1984). This idea parallels the scientific method we know today, which follows a similar pattern and uses one step to build off another.

While the theory was originally based on pedagogical thinking, neo-educationalists have expanded its scope to include higher education (Kolb and Kolb, 2005). Kolb's learning model condensed and transformed this model from experimentation and into a more educationally bound, cognitive context (Kolb, 1984). His current model is also cyclical in nature but instead includes the concrete experience (generally situated in a societal context), reflective observation, abstract conceptualization, and finally fits into the active experimentation context of Dewey's original model (Figure 1.3).

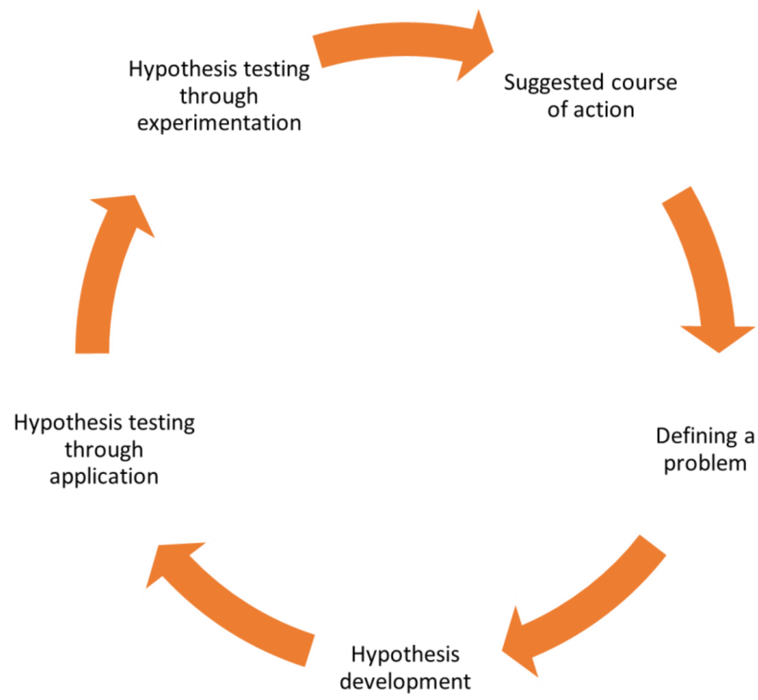

Figure 1.2. Dewey's cyclical experiential learning model

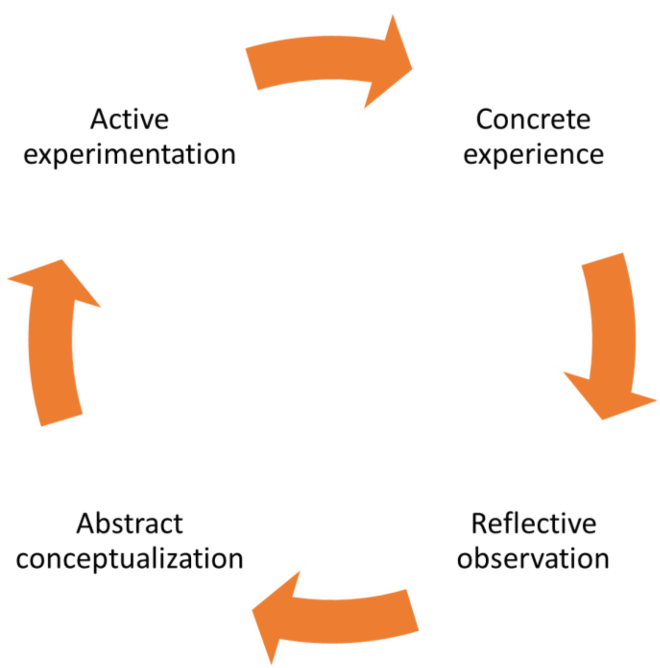

Figure 1.3. Kolb's cyclical learning model

This new movement has been incredibly impactful in the field of science. Currently, many schools are working to integrate experiential learning to tackle challenging concepts (Wei and Woodin, 2015). Many of these efforts incorporate aspects from project or problem-based learning, an idea that builds on the postulates of John Dewey and Jean Piaget, another highly regarded philosopher of education (Kolb, 1984). Experiential forms of learning can be constructive for dealing with issues that Dewey considered most important: those impacting society. The project used the basis of experiential learning theory through the concrete experiences of outreach, research, project-based learning, and citizen science as a model to evaluate gains in student understanding in the context of climate change education (Figure 1.4).

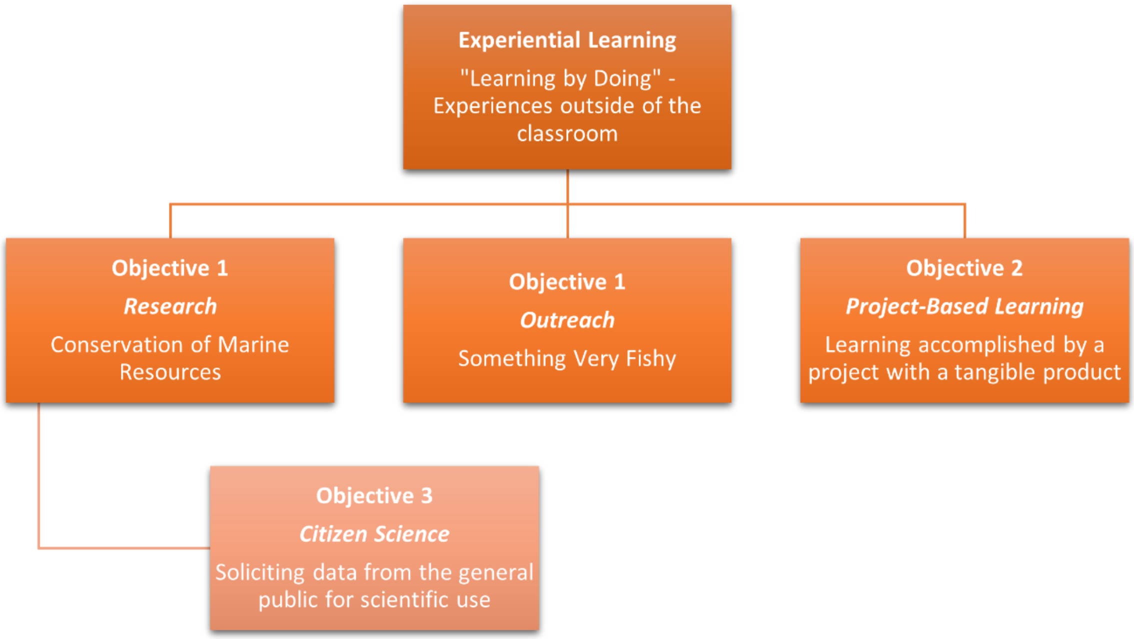

Figure 1.4. Connection of each project component to experiential learning *and overall objectives.* Objective 1: Understand the impact of experiential research and outreach education on alumni; Objective 2: Assess the benefit of implementing project-based learning in an outreach program; Objective 3: Understand the impact of integrating experiential citizen science with elementary and undergraduate students.

Problem Description

Climate change and anthropogenic impacts on the ocean is a critical issue facing society. Coral reefs are declining, anthropogenic marine debris is at an all-time high, and overfishing is decimating top predators (Harborne et al., 2017). These are all complex, yet solvable, issues when addressed by a collective effort to combat human impacts

(Duarte et al., 2020). Despite the apparent relation of humans to these issues, it is rarely discussed in educational settings, often due to political or social biases associated with climate change (Colston and Ivey, 2015). The lack of integration into grade school education is even more disheartening, often resulting in a lack of understanding of climate science for entering undergraduates in science (Corner et al., 2015). Studies have shown that an increase in climate change education can lead to higher engagement with climate change (Corner et al., 2015; Stevenson et al., 2018). This engagement is especially true with students directly involved in research or outreach with issues surrounding climate change, such as those in marine biology (Corner et al., 2015). Higher interest in marine biology or feelings of importance in marine science in students can also create a higher desire to incorporate conservation into one's life (Guest et al., 2015; Lucrezi et al., 2018). However, due to the lack of opportunities for studying climate change and marine science, most knowledge of climate change and ocean health is accomplished through experiential learning outside of the classroom (Valdez et al., 2018).

Clemson University's Creative Inquiry (CI) program is one of many experiential learning programs provided at undergraduate universities that allow faculty, graduate mentors, and undergraduate students to work together to accomplish goals set by faculty advisors. These can range from cutting-edge research to changes in community practice through outreach. Students enrolled in Clemson's program electively join the course based on faculty recommendations or approval and receive between 1-4 credit hours for each semester. My study used two Creative Inquiries focused broadly on marine science in an outreach and research context (respectively): Something Very Fishy and Conservation of Marine Resources. Using the Something Very Fishy CI, I assessed the benefits associated with Project-Based Learning (PBL) and citizen science.

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CHAPTER TWO
UNIVERSITY EXPERIENCES OF MARINE SCIENCE RESEARCH AND OUTREACH BEYOND THE CLASSROOM

Introduction

Climate change has been especially detrimental to one of the most economically and biologically important ecosystems on Earth: the ocean (IPCC, 2019). Problems such as rising temperatures, increased storm intensity, ocean acidification, and decreasing water quality are causing drastic declines to reef ecosystems (Harborne et al., 2017). Although the ocean is experiencing these issues, many students are not being exposed to climate change education (NCSE, 2020) and ocean literacy (Gough, 2017; Fauville, 2019). The National Oceanic and Atmospheric Administration (NOAA) has attempted to fill this void through the creation of additional science standards centered on seven foundational ocean literacy principles which address vital issues related to climate change and the marine ecosystem (NOAA, 2020). However, many students in majors outside of marine biology have not been exposed to these principles, creating a need to integrate these topics outside of the traditional classrooms (Gould et al., 1979; Gough, 2017; Squarcina and Pecorelli, 2017). Experiential learning is a widely accepted integrative concept used in modern educational techniques (Kolb and Kolb, 2005). This "learning by doing" theory is based on the transaction of learning between students and their environment in which students contribute to their surroundings while their surroundings have internal impacts on them (Kolb, 1984).

Experiential learning can be used in several formats but is commonly found in undergraduate research experiences (UREs) and outreach experiences. UREs in STEM fields often place undergraduates into a research project alongside a faculty or graduate student mentor and are an effective way to give undergraduates their first encounters with biological inquiry and scientific communication (Nagda et al., 1998). Previous literature has found that participation in UREs can lead to increases in objective knowledge, perceived knowledge (confidence), science communication skills, and science identity, ultimately translating to more opportunities for advanced degrees, and a higher likelihood to graduate (Nagda et al., 1998; Bauer and Bennett, 2003; Junge et al., 2010; Gilbert et al., 2014; Linn et al., 2015; Weaver et al., 2018). However, measured changes in personal attitudes and opinions towards a subjective research topic are not regularly presented in literature. Like UREs, outreach experiences can also lead to increases in perceived knowledge, science communication skills, and science identity (Rao et al., 2007; Bergerson et al., 2014; Carpenter, 2015). Additionally, outreach programs have been shown to alter personal views towards pervasive issues (Bergerson et al., 2014; Carpenter, 2015). Although these outcomes can be similar, outreach experiences in some instances, integrate college undergraduates with K-12 students to begin conversations about pervasive scientific issues while teaching STEM concepts and principles. In return, this provides undergraduate students with a professional development opportunity that facilitates communication and mentorship with the next generation of students (Rao et al., 2007; Bergerson et al., 2014; Nelson et al., 2017; Knippenburg et al., 2020). While UREs provide undergraduates the opportunity to investigate and generate new ideas related to the field of interest, outreach experiences generally rely on conveying previously understood and well-defined topics to others (Kardash, 2000; Rao et al., 2007; Junge et al., 2010; Wei and Wooding, 2011; Carpenter, 2015; Linn et al., 2015). Unfortunately, increases in objective content knowledge are not regularly measured in outreach programs. To the best of my knowledge, previous studies have not looked comparatively across research and outreach programs that address similar topics.

Factors Affecting Gains in Experiential Learning

Both UREs and outreach experiential learning experiences primarily utilize the apprenticeship model to pair students with a graduate student or faculty member to pursue a project (Nagda et al., 1998; Rao et al., 2007; Junge et al., 2010; Wei and Woodin, 2011; Auchincloss et al., 2014). The relationships between mentors and undergraduate students have been shown as one of the most vital components of a successful college experience for undergraduates (Nagda et al., 1998). Students who are paired with mentors that emphasize career success and direction are more likely to overcome achievement gaps and find career success (Martin et al., 2013; Linn et al., 2015). Programs like UREs and outreach can also help to fill gaps in mentorships that many students experience upon entering college (Robnett et al., 2018).

Much like mentorship, length of experience can have profound effects on the success of these programs (Bauer and Bennett, 2003). In an analysis of over sixty different UREs, one study found that the first year of involvement in the program led to almost no gains in identity, self-efficacy, concept retention, or relevant science skills

(Linn et al., 2015). However, the longer the participants were enrolled, the more gains were seen in all areas (Linn et al., 2015). Similar results were found in a study conducted on undergraduates participating in K-8 STEM outreach (Nelson et al., 2017). Additionally, a study by Adedokun et al. (2014) found that students who participated in their summer URE found large gains in research skills and self-efficacy when undergraduates were enrolled for longer periods of time. Other studies have not used this as a focal point as this can be a difficult metric to measure in programs with a set length of enrollment (Junge et al., 2010; Lynch et al., 2010; Carpenter, 2015).

Creative Inquiry Program – Clemson University experiential learning

Clemson University, South Carolina, provides a creative inquiry program beyond the traditional classroom that allows undergraduates to partner with graduate students and faculty mentors on a broad range of experiential research projects. Many undergraduates have the freedom to rotate between creative inquiry teams as their interests evolve, or as a method to diversify their skillsets; an aspect that is unique to this program. Faculty receive modest grants to support the activities of the team. Most importantly, many of these programs encourage students to enroll for multiple semesters with the end goals being publications, presentations, research grants, and/or patents.

My research focused on two creative inquiry teams. The Conservation of Marine Resources (CMR) creative inquiry team (established in 2008) is focused on marine and behavioral ecology field research exploring the impacts of climate change and habitat loss on the behavior and ecology of marine invertebrates and reef fishes (Figures 2.1A –

C). CMR is only advertised to students through their professors and academic advisors. Students must inquire and apply to CMR by submitting a personal statement and curriculum vitae. This creative inquiry primarily attracts students majoring in Biological Science, Animal Veterinary Science, Environmental Science, Wildlife and Fisheries Biology, and Biosystems Engineering. Applicants are then interviewed and selected on a competitive basis determined through GPA, research and animal care experience, SCUBA experience, and overall interest in one of the program's ongoing projects. These parameters are used to ensure that the creative inquiry can support the students' goals, and that students are able to support the projects. Once accepted, all students that are approved by their mentor are invited to continue in the program until they graduate. Students in CMR learn various methods of quantifying species abundances and behaviors using imaging software and statistical analysis programs. Those team members with open-water SCUBA certifications may also participate in the data collection in the field during the summer semesters. All students are required to participate in weekly scientific paper discussion groups on current topics in marine science and partake in science communication involving either a poster or oral presentation at a university, regional, or national conference during the school year. Some students are also given the opportunities to aid in the publication process based on their skills and interests.

Figure 2.1. Conservation of Marine Resources (CMR) creative inquiry team (A) learning marine species identification, (B) conducting marine ecology research, (C) presenting research findings at a university Symposium. Something Very Fishy (SVF) creative inquiry team (D) building coral reef theatrical set, (E) marine veterinarian sharing live invertebrates, (F) park ranger exploring sea turtle nesting beach. Photo credits with permission: (A) Pete Bouwma, (B) Kylie Smith, (C-D) Michael Childress, (E-F) Robert Bradley. All permissions obtained.

The Something Very Fishy (SVF) creative inquiry team (established in 2018) is a marine science educational outreach team focused on teaching the principles of climate and ocean literacy to elementary students (Figures 2.1D – F). SVF is actively advertised through the Creative Inquiry program, and through multiple departmental email lists. This creative inquiry attracted students majoring in Biological Science, Animal Veterinary Science, Environmental Science, Education, Psychology, and Wildlife and Fisheries Biology. Any student who inquires about joining SVF is immediately cleared to enroll due to the introductory nature of the program. Students who participate in the program by attending weekly meetings and assist in developing STEAM exhibits (explained in the following sentences) are automatically invited to continue until graduation. Involvement in this outreach program includes a Broadway style musical theater performance followed by various science exhibits to help educate elementary school students about ocean conservation. SVF undergraduate students learn about threats to ocean health, introductory marine science, climate change threats, learning styles, and storytelling concepts through lectures, group discussions, and the creation of learning modules. These students are also responsible for the development of interactive exhibits where they portray different careers in science (coral biology, marine animal veterinarian, park ranger, SCUBA engineer, sea turtle biologist, etc.) as docents on an imaginary field trip to the Florida Keys. The STEAM exhibits seek to combine an arts and science approach to teaching ocean literacy principles. After the children attend the *Something Very Fishy* musical theater production, conducted by a community partner of the Clemson SVF creative inquiry team, the SVF undergraduate students teach the elementary school students about ocean conservation while portraying a career in science.

In this chapter, I compare students that have participated in two different creative inquiry teams, Conservation of Marine Resources (2008-2020) and Something Very Fishy (2018-2020). Previous studies have found alumni to be accurate representation of undergraduate perceptions on URE's (Adhikari and Nolan, 2002). Alumni are also more likely to understand how the program impacted their career, personal gains, and attitudes, as well as concept retention (Junge et al., 2010). Thus, this study uses CMR and SVF Creative Inquiry alumni to measure gains of these programs on undergraduates. The purpose of this study aims to understand the unique gains for undergraduate students of a marine biology outreach experience versus a marine biology research experience, versus students that experienced both. Success in these experiences is determined through three metrics: (1) knowledge, (2) career, and (3) attitudes (Table 2.1). These gains are also compared to length of involvement (duration) and mentorship experience in the type of creative inquiry program (research versus outreach versus both).

Table 2.1. Dependent variables affected by program involvement in categories related to the three gains: knowledge, careers, and attitudes.

Knowledge	Careers	Attitudes
Objective Knowledge of Ocean Literacy Concepts	Importance of Marine Science on Career	Science Identity and Belonging
Perceived Knowledge of Marine Science	Importance of the Program on Graduation	Perception of Climate Change Threat on Marine Environment
Marine Science Resource Skills	Pursuance of STEM Career	Importance of Conservation on Daily Life
Marine Science Stewardship Skills	Pursuance of Further Education	
Marine Science Communication Skills		

Methods

Undergraduate Student Survey:

A 35 question Qualtrics survey was created to collect information regarding independent variables (duration in the program, type of program and mentorship experience), dependent variables (knowledge, career, attitudes), and several potential demographic covariates (age, gender, ethnicity, ideology). Survey questions were approved by the Clemson University Institutional Review Board (IRB2018-497) (Tables 2.2-2.6). Survey invitations were sent by e-mail from the program leads to all alumni of SVF outreach and CMR research creative inquiry teams, including those who had participated in both. All respondents were given instructions on how to access the survey and were assured anonymity in their responses. Surveys were sent to a total of 121 alumni, 71 who participated in the outreach program, 37 in the research program, and 13 from both. Respondents answered questions regarding mentor experience and overall experience for the program(s) in which they were involved. Students who were involved in both programs answered all questions. Alumni in outreach were also asked what roles they filled during their participation, while previous research students were asked to identify in which project they participated. Respondents who participated in both were asked both sets of questions. All respondents were asked questions related to their gender, age, and political affiliation (ideology) as well (Table 2.3).

Table 2.2. Survey questions used to determine independent variables.

Program Type *Which Creative Inquiry(ies) have you participated in?*
Something Very Fishy (Outreach) Conservation of Marine Resources/Marine Ecology (Research) Both
Duration *Indicate all semesters you participated in the Conservation of Marine Resources or Marine Ecology Creative Inquiry and/or Something Very Fishy. Click all that apply.*
Mentor Experience (1 = Strongly Disagree to 5 = Strongly Agree) *Thinking back to your experience with your Conservation of Marine Resources or Marine Ecology mentor(s) and/or Something Very Fishy mentor(s), please indicate your level of agreement with the following statements:*
My mentor(s) helped provide direction and guidance on professional issues My mentor(s) acknowledged my contributions appropriately My mentor(s) actively listened and provided useful critiques My mentor(s) motivated me to improve my work Overall, I was satisfied with my mentor(s) *Cronbach's alpha (Conservation of Marine Resources/Marine Ecology) = 0.93;* *Cronbach's alpha (Something Very Fishy) = 0.92*

Table 2.3. Survey questions related to demographics used as covariates in all models.

Age (text entry)
How old are you?
Sex (female)
What is your gender?
Male
Female
Non-binary, gender fluid, or gender non-conforming
Other (text)
Prefer not to disclose
Ideology
Generally speaking, would you describe your political views as
Very conservative
Somewhat conservative
Moderate
Somewhat liberal
Very liberal

Table 2.4. Survey questions used to determine gains in conceptual understanding.

Objective Knowledge of Ocean Literacy Concepts (1 = Definitely False to 4 = Definitely True) *Indicate the degree to which each is true*
The Earth has one big ocean with many features
The Earth has always had an ocean
The ocean is a major influence on weather and climate
The ocean makes Earth hotter*
All life arose in the oceans
The ocean and humans are interconnected
The ocean is largely unexplored
Perceived Knowledge of Marine Science (1 = Nothing at all to 5 = A great deal (expert-level)) *How much do you know about marine sciences?*
Marine Science Communication Skills (1 = Strongly Disagree to 5 = Strongly Agree) *I am confident in my ability to communicate about marine science to my friends and family*
Marine Science Resource Skills (1 = Strongly Disagree to 5 = Strongly Agree) *I am confident that I can find resources to help me keep up with learning more about marine science*
Marine Science Stewardship Skills (1 = Strongly Disagree to 5 = Strongly Agree) *I am confident that I can engage in stewardship behaviors to help the oceans*

*Reverse coded variable

Table 2.5. Survey questions used to determine influences in career and career development. Asterisks denote a STEM career field.

Importance of Marine Science on Career
(1 = Not at all important to 5 = Extremely important)
Please indicate how important marine science is to your career
Importance of the Program on Graduation
(1 = Strongly Disagree to 5 = Strongly Agree)
Please indicate your level of agreement with the following statements
Participating in CI made me reconsider my career path to one focused on marine biology
Communication skills I learned in CI have helped me in my career
Conservation strategies I learned in CI have helped me in my career
Research skills I learned in CI have helped me in my career
CI assisted in making me more confident in my career field
CI assisted in making me more confident in my career field
Cronbach's alpha = 0.83
Pursuance of STEM Career
(Medical, Research, other STEM field)
What is your current job/career field?
Education
Medical*
Research*
Communication
Industry*
Have not yet graduated
Graduate/continuing student (text entry)
Other (text entry)
Pursuance of Further Education
(Graduate/continuing student, Have not yet graduated)
What is your current job/career field?
Education
Medical*
Research*
Communication
Industry*
Have not yet graduated
Graduate/continuing student (text entry)
Other (text entry)

Table 2.6. Survey questions used to decipher attitudes about science, marine science, and climate change.

Science identity and belonging (1 = Strongly disagree to 5 = Strongly agree) *Please indicate your level of agreement with the following statements*
I have a strong sense of belonging to the science community
I feel like I belong in the field of science
Scientific work is appealing to me
It is important to take part in science communication activities with non-science personnel
I have a duty to take part in science communication activities targeting the general public
I think discussing new theories and ideas about science is important
I think it is valuable to conduct research that builds the world's scientific knowledge
I think science can solve many of today's world challenges
I feel discovering something new in science is thrilling
Cronbach's alpha = 0.85
Perception of Climate Change Threat on Marine Environment (1 = No threat at all to 5 = High threat) *What level of threat does each of the following topics pose to ocean health?*
Ocean warming
Plastic (or other trash) pollution and marine debris
Ocean acidification (lower pH)
Loss of endangered species
Nutrient pollution (eutrophication)
Overfishing
Habitat Loss
Diseases and pathogens
Importance of Conservation on Daily Life (1 = Not at all important to 5 = Extremely important) *Please indicate how important conservation is to you in your daily life*

Survey Measures

Alumni of all classifications were asked to indicate their perceived knowledge of marine science concepts on a scale of 1-5 (1 = nothing at all, 5 = expert-level) (Table 2.4). Because an ocean literate person is defined as someone familiar with the seven ocean literacy principles, respondents were given each principle and asked to indicate how true they felt each was on a four-point scale (1 = Definitely False, 4 = Definitely True) (NOAA, 2020). Alumni were also asked to indicate if their program involvement influenced their communication, research, and stewardship skills (1 = Strongly Disagree, 5 = Strongly Agree). Career choice was divided by STEM careers (medical, research, or other career entered by text related to a STEM career), continuing student, or other (Table 2.5). These responses were recorded as binary variables. Respondents were asked if various skills learned in their program assisted them in their career. These skills included communication, research, and conservation strategies which were rated on a scale of 1-5 (1 = strongly disagree, 5 = strongly agree). Finally, respondents were asked to identify the importance of marine science overall in their current career fields on a scale of 1-5 (1 = Not at all important, 5 = Extremely important). Science identity and belonging was assessed through several statements related to attitude (Table 2.6) (Tallapragada et al., 2021). These statements included the importance of discussing new ideas in science, the value of research, the ability of science to solve problems, and the feeling of discovery as "thrilling". Responses were rated on a scale of 1-4 (1 = Not at all like me, 4 = Very much like me). Belonging in science was assessed through respondents' answers to direct statements on belonging in a science-related field. Statements assessing willingness to communicate about science to the public were also used to indicate belonging. All statements were rated on a five-point scale (1 = Strongly disagree, 5 = Strongly agree). Alumni were asked to rate their perception of critical ocean health issues on a scale of 1-4 (1 = No threat at all, 4 = High threat). Finally, respondents were asked to rate how important conservation was on their daily lives (1 = Not at all important, 5 = Very Important). All semesters that a respondent participated in any program were summed to calculate total duration of involvement. Program participation was broken down by category: outreach, research, or both. Mentor experience was determined by averaging questions related to mentor experience (Table 2.2). All scales were found to be reliable (Cronbach's alpha > 0.80).

Variables were composed of a variety of survey questions. Single question continuous variables derived from a single response on a five-point scale: Ideology (Table 2.3), Perceived Knowledge of Marine Science (Table 2.4), Marine Science Communication Skill (Table 2.4), Marine Science Resource Skill (Table 2.4), Marine Science Stewardship Skill (Table 2.4), and Importance of Marine Science on Career (Table 2.5). Each question had a single variable associated with it. Multiple question continuous variables derived from the average responses on a five point scale: Mentor Experience (Table 2.2), Objective Knowledge of Ocean Literacy Concepts (Table 2.4), Importance of the Program on Graduation (Table 2.5), Science Identity and Belonging (Tables 2.6) and Perception of Climate Change Threat on Marine Environment (Table 2.6). These variables were comprised of a combination of various questions. All multiple question variables had a Cronbach's alpha > 0.80 to assure composite score reliability.

Two binary variables were constructed from a single multiple-choice survey question "*What is your current job/career field?*" (Table 2.5): Pursuance of STEM Career (Yes = Medicine, Research, Other STEM; No = Education, Communication, Industry, Not yet graduated, Graduate student, Other Non-STEM); and Pursuance of Further Education (Yes = Graduate student, Not yet graduated; No = Education, Medical, Research, Communication, Industry, Other).

Statistical Analyses

I used a multiple model comparison approach (Burnham and Anderson, 2002) to evaluate which factors were most important for each of my dependent variables. The multiple linear regression models always included the three demographic covariates: gender (female only due to demographic distribution), age, and ideology (very conservative to very liberal). Each model then included from zero to four independent variable terms: semesters enrolled in creative inquiry (duration), ratings of CI team leader mentorship (mentor), and creative inquiry type (CMR, SVF or both). All possible combinations of independent variables were evaluated and compared using a minimum Akaike information criterion (AICc) ranking (Appendix Table A-1). Best fit models were defined as those with ΔAIC scores of less than two (Table 2.7). Because the "pursuance of further education" and "pursuance of a STEM career" were binary dependent variables, I used logistic multiple regressions with a binomial distribution.

Table 2.7. Multiple linear regressions and logistic regressions (indicated by an asterisk*) with AICc scores less than 2. These show the multiple models run for each dependent variable and its category. Individual factors significant in each model are indicated in *italics* ($P < 0.10$), **bold** ($P < 0.05$) and **<u>bold underlined</u>** ($P < 0.01$).

					Knowledge					
	Age	Gender	Ideology	Duration	Mentor	Research	Outreach	Overall Model		
	β1	β2	β3	β4	β5	β6	β7	F	P	Adj R^2
Perceived Knowledge of Marine Science	0.0066	0.1293	0.0395	*0.1014*	**0.5824**	--	--	2.8304	0.0369	0.2337
	-0.0148	-0.0429	0.0473	--	**0.7002**	--	--	2.2155	0.0951	0.1394
Marine Science Communication Skills	0.0189	-0.0075	0.0570	*0.0785*	**0.7357**	--	--	3.8940	0.0095	0.3253
	0.0023	-0.1409	0.0630	--	**0.8269**	--	--	3.7663	0.0152	0.2694
					Careers					
	Age	Gender	Ideology	Duration	Mentor	Research	Outreach	Overall Model		
	β1	β2	β3	β4	β5	β6	β7	F	P	Adj R^2
Importance of Marine Science on Career	*-0.1258*	-0.1329	0.0463	**0.2164**	--	--	--	3.8630	0.0136	0.2762
	-0.1082	-0.0212	0.1314	**0.1929**	0.5809	--	--	3.4084	0.0175	0.2864
Importance of the Program After Graduation	-0.0468	0.4967	0.1511	--	**0.6629**	--	--	3.1520	0.0307	0.2230
	Age	Gender	Ideology	Duration	Mentor	Research	Outreach	Overall Model		
	β1	β2	β3	β4	β5	β6	β7	c^2	P	
Pursuance of Further Education*	*-1.0985*	-1.2829	-0.1430	*0.4276*	--	--	--	18.657	0.0009	
	-1.3261	-1.8268	-0.6023	**0.5447**	-2.3397	--	--	20.855	0.0009	
	-0.7826	-1.8452	-0.2492	--	--	--	--	14.341	0.0025	
					Attitudes					
	Age	Gender	Ideology	Duration	Mentor	Research	Outreach	Overall Model		
	β1	β2	β3	β4	β5	β6	β7	F	P	Adj R^2
Science Identity and Belonging	**-0.0451**	0.0071	0.0218	**0.0685**	--	--	--	4.5380	0.0065	0.3205

Perception of Climate Change Threat on the Marine Environment	0.0270	0.1244	**0.1226**	**0.0515**	--	-0.2261	0.1809	4.0953	0.0057	0.3823
	-0.0109	0.1757	**0.1185**	*0.0349*	--	--	--	3.7887	0.0148	0.2710
	-0.0199	0.1054	**0.1150**	--	--	--	--	3.6885	0.0240	0.2118
	0.0152	0.0397	**0.1132**	--	--	**-0.3488**	-0.0382	3.4501	0.0166	0.2899

Results

Demographics

I received a total of 37 responses for a 31% participation rate, notably higher than Clemson University alumni's normal response rate of less than 10%. Alumni were asked to identify which program they participated in (11 in outreach, 15 in research, 11 in both) as well as their length of participation (Table 2.2). Respondents that failed one or more attention checks were removed from the dataset to ensure accurate answers, this resulted in a total of 31 usable responses from alumni who participated in the programs (N = 9 in outreach, N =13 in research, N = 9 in both). Participants ranged in age from 20-33, with the majority between 20-26 (M = 24, SD = 3.58). Most subjects identified as female (N = 25), with only five males and one who preferred not to disclose their gender, which was representative of gender distribution in both the program and across majors who participate in the programs (Table 2.8). My sample consisted mainly of Caucasian alumni (N = 29) with only two alumni identifying as part of an underrepresented minority group (Black or African American N = 1; Asian N =1). These numbers are in alignment with university demographics as well as demographics across majors who participate in the program and was representative of both programs' demographics (Table 2.8). I defined ideology as the political views held by alumni, which ranged from (1) Very Conservative to (5) Very Liberal. Ideology was selected due to its potential influence on student attitudes towards divisive science topics such as climate change (Guy et al., 2014; Tallapragada et al., 2021). Additionally, ideology has been shown to underly epistemic cognition in students, with political beliefs driving trust in messengers (Säther, 2003).

While I had a range of responses regarding political ideology, the majority identified as somewhat to very liberal (M = 3.58, SD = 1.26).

Table 2.8. Demographic information related to sex and race/ethnicity across the university level, major level (demographics across most majors (~95% of students) who actively participate either program including Animal Veterinary Sciences, Environmental and Natural Resource Sciences – Conservation Biology, and Biological Sciences), program level, and survey level. Upper-level data was retrieved from Clemson University's 2020 open-access enrollment data. University and major demographics were extremely similar throughout all years of participation.

Gender	University	Majors	Program	Survey
Male	50.6%	29.4%	20.5%	14.7%
Female	49.4%	70.6%	79.5%	85.3%
Race/Ethnicity	University	Majors	Program	Survey
White	80.2%	78.6%	88.5%	88.6%
Hispanic	6.0%	5.9%	2.6%	0.0%
Black	5.8%	7.3%	3.8%	2.9%
Asian	2.7%	3.3%	3.8%	2.9%
Native	0.3%	0.4%	0.6%	0.0%
Other	5.0%	4.5%	0.6%	0.0%
Total Individuals	20,878	2,165	156	35

Knowledge

Perceived knowledge of marine concepts was influenced the most by a positive mentor experience ($\beta = 0.5824$, $p = 0.0375$) and secondarily by time in the creative inquiry team ($\beta = 0.1007$, $p = 0.0511$). However, the creative inquiry type did not influence perceived knowledge, nor did any of the demographic covariates (Table 2.7). Marine communication skills were influenced the most by a positive mentor experience ($\beta = 0.7357$, $p = 0.0047$) and secondarily by time in the creative inquiry team ($\beta = 0.0785$, $p = 0.0878$). Like perceived knowledge, the creative inquiry type did not influence marine communication skills, nor did any of the demographic covariates (Table 2.7). I did not find any relation between creative inquiry type, duration, or mentor experience on stewardship or resource skills. Objective knowledge of ocean literacy principles was also not related to creative inquiry type, duration, or mentor experience. However, the knowledge of ocean literacy principles was relatively high in all creative inquiry teams: outreach (M = 3.53, SD = 0.31), research (M = 3.51, SD = 0.24), and both (M = 3.51, SD = 0.22).

Career

Alumni respondents primarily held careers in the STEM category (N = 12) or were continuing students in a science field (N = 12) with only 7 holding jobs in communication or another field. The importance of marine science on career was primarily influenced by the time in creative inquiry ($\beta = 0.2164$, $p = 0.0252$) and secondarily by age ($\beta = -0.1258$, $p = 0.0797$). The influence of alumni age indicated that the longer they had been out of the program, the less important marine science was on their career. Neither mentorship, creative inquiry type, gender, or ideology influenced the importance of marine science on their career (Table 2.7). However, the importance of the program after graduation was primarily influenced by positive mentorship ($\beta = 0.6629$, $p = 0.0155$), with those who had more positive mentor experiences finding the program more important after they graduated (Table 2.7). Those who were younger (log regression $\chi^2 = -1.098$, $p = 0.0535$) or involved in creative inquiry for many semesters (log regression $\chi^2 = 0.4276$, $p = 0.0729$) were more likely to continue their education (Table 2.7). All students who indicated that they were continuing students, also stated that it was in a STEM field. There was also no significant effect of creative inquiry type on the importance of the skills learned in the program on the alumni's careers.

Attitudes

A sense of science identity and belonging increased primarily with time in creative inquiry ($\beta = 0.0685$, $p = 0.0196$) and decreased secondarily with age ($\beta = -0.0451$, $p = 0.0396$). Interestingly, those who were younger had a stronger sense of science identity and belonging. Neither mentorship or creative inquiry type influenced science identity and belonging (Table 2.7). Students who participated in both programs were more likely to have higher perceptions of threats to the ocean's health versus those who only participated in the research program ($\beta = -0.3488$, $p = 0.0413$). However, ideology was an even stronger driver in these perceptions of threat ($\beta = 0.1132$, $p = 0.0074$) with very liberal alumni showing higher levels of perceived threat (Table 2.7). The importance of conservation on daily life was not impacted by creative inquiry type, duration, or mentorship experience.

Overall Experience

It is worth noting that alumni from both CMR and SVF felt positively about their experience in their respective creative inquiry teams (research: M = 4.54, SD = 0.52; outreach: M = 4.44, SD = 1.67; both M = 4.83, SD = 0.25). This was also true for mentorship experience (research: M = 4.55, 0.64; outreach: M = 4.67, SD = 0.55; both: M = 4.80, SD = 0.33). Respondents also indicated strong positive feelings towards their program(s) through the additional comments left at the end of the survey (Table 2.9).

Table 2.9. All quotes from the survey responses to: "If you have comments on your experience with the Creative Inquiries or this survey, please let us know below."

Responses
My entire career path was transformed because of my experiences in these CIs. I can't overstate the effect they've had on my life.
Creative inquiry was the most valuable part of my Clemson experience. Without CI, I would have next to nothing positive to say about Clemson bar the environment. CI allowed me to experience the research process for myself, from start to finish. It taught me so much about the practical applications of research and scientific work that I never learned in class. It was also an incredible boon to my personal life, as it was the only place I met like-minded people to socialize with and whom I enjoyed working with. I was fortunate to take part in two CIs with this lab, both of which gave me unique and priceless experiences that I will forever be grateful for.
Without CI, I wouldn't have been prepared for graduate school the way that I am! I miss being apart of this great program but I am so appreciative of the support and training you all provided for me.
I participated in Creative Inquiry during the Fall 2009, Fall 2010, and Spring 2011 semesters, but I was only able to select the Spring 2011. Additionally, I graduated in 2011, but the earliest year I was able to select in the survey was 2012.
I did not put all of the correct semesters for my time working in the CI. I was in the lab for Spring 2019, Summer 2019, Fall 2019 and helped some during Spring 2020. Sorry for the inconvenience this year has made me lose track of time.
I had a wonderful experience in this creative inquiry! I loved watering my love and appreciation for the ocean and its wildlife through this research experience.
I don't remember what semester/semesters I participated in CMR, but I graduated from Clemson in May 2010.
I actually graduated in 2011 and participated in CMR from 2009-2011 (2011 graduation wasn't an option on this survey). When I look back on my time at Clemson, CMR was one of the most worthwhile things I participated in. It taught me so much about not only the research process, but also what I was capable of. I love telling people about my blue crab research, my trip to the keys, and my presentations at the Benthic Ecology meetings. Dr Childress was one of those professors that truly cared about his students and I'm glad to see he has continued with CI.
Loved it! So glad to be a part of it! Very beneficial as an undergrad and staging involved as a graduate student !
I loved this experience in college but also was super low on the totem pole. I got to hand feed crabs and lobsters, always wanted to be more involved but was not a master's track for con bio.
This CI was the best part of my undergrad career and the most enjoyable. A lot of times people don't think that marine and environmental science apply to the medical/public health field but I've been able to be an advocate for how they impact each other including through climate extremities (natural disasters), environmental

changes impacting housing and food availability, and pollution/toxins negatively impacting health. This CI also improved my research skills, communication skills, and professionalism.
It was a great experience, I would totally do it again if I could!

Discussion

The purpose of this study was to determine the effects of both an outreach and research creative inquiry on undergraduate alumni in relation to marine and climate change knowledge and skills, career choice, and attitudes. I found evidence that creative inquiry impacted perceived knowledge and skills significantly through mentorship experience, but this did not depend on the creative inquiry type (research versus outreach) or duration. Career choices and factors related to career choices were impacted by duration and mentorship experience, but not creative inquiry type. I also found that alumni indicated a higher sense of science identity and belonging the longer they were enrolled in creative inquiry as well as better understanding of threat perception, which was also influence by personal ideology. Creative inquiry type influenced attitudes towards ocean threats.

Knowledge

In both the outreach and research creative inquiries, graduate mentors, and a primary faculty advisor partner with students in small groups or individually. I found that perceived knowledge of marine science was higher in alumni who rated their experience with their mentors highly. I also observed gains through positive mentorship in one area of science that is not typically addressed in lecture-style STEM classes: communication. In the modern field of marine science, communication is one of the most critical skills not taught beyond the general education requirement in universities (Gill and Golding, 2001). Students within both programs engage in various forms of science communication including poster presentations, science exhibit facilitation, oral presentations, blog posts, and discussion leadership. These presentations are normally given and subsequently critiqued by their mentors before presentation to a general audience. Working closely with mentors to understand the concepts and hypotheses they are presenting allows students to simultaneously increase their confidence in their research while promoting strong communication (Kardash, 2000; Linn et al., 2015). My findings were similar to other studies who found that good experiences with mentors also leads to higher self-efficacy and confidence, particularly in STEM fields (Kardash, 2000; Lopatto, 2007). Students with higher self-efficacy in science become more engaged with science and have higher retention rates, as well as a better understanding of the discipline overall (Andrew, 1998; Sawtelle et al., 2012; Macphee et al., 2013; Williams and George-Jackson, 2014). This can be particularly impactful to those in underrepresented groups as well as women (Macphee et al., 2013; Ballen et al., 2017). Similar gains were seen through longer involvement with the program. Because students could potentially enroll anywhere from one semester to all four years of their college career in either or both programs, students generally become involved in multiple projects, increasing their exposure to and confidence in different subject areas of marine biology. Prolonged involvement lends its way to more opportunities for scientific communication and facilitates their ability to hone their craft over time (Carpenter, 2015). These findings have numerous implications for students' future motivations in science and gives evidence to the successful nature of the programs.

Careers

Mentors throughout all parts of a student's undergraduate experience can have significant influences on the skills they acquire in college, their desire to continue their higher education, and ultimately the career they choose to pursue (Houser et al., 2013; Langholz and Abeles, 2014). Students in creative inquiry teams who felt encouraged and heard by their mentor believed that their program involvement was critical to their success after graduation. Most alumni also indicated that they were involved in a STEM field whether it was continuing education or as a career. Those that were involved in the program for longer durations were more likely to continue their education, although age was also a contributing factor. Findings from increased duration suggests that those involved in the program for longer are more likely to continue their education, particularly when they are between the ages of 20-26, which is not an atypical finding as other programs have found that long-term involvement, or greater involvement with a project can lead to higher immediate motivation to pursue graduate school (Russell et al., 2007; Linn et al., 2015). Because many participants were between the ages of 20-26, further research is needed to evaluate the potential impacts that time spent in this program have on older alumni who are more advanced in their careers.

Attitudes

The perception of climate change threats on ocean health was higher for those who participated in both programs than research alone. Students are taught directed lessons on climate change threats in the outreach program and later communicate them to elementary students. Those that participate in research later couple this primary knowledge with research projects that attempt to combat the threats of climate change. Techniques like this that connect students directly to the ocean have the potential to contribute to undergraduates' understanding of climate change education (Gough, 2017; Squarcina and Pecorelli, 2017). Thus, pushing to involve undergraduates in community ocean literacy outreach, particularly at research-centered universities could be beneficial for increasing climate change awareness in both undergraduates and the public (Plankis and Marrero, 2010; Visbek, 2018). It is also important to point out that ideology was one of the strongest significant negative factors in all models. Previous literature has found that political ideology can influence the perception that many students have on perceived risks of other controversial scientific topics (Ferguson et al., 2020). Other studies have also found that by incorporating previously held values and beliefs into educational platforms, one is more likely to be accepting of scientific concepts and understand these concepts better (Miyake et al., 2010; Corner et al., 2015). While not negating the important impact of program type in this study, it does provide insight into the extreme influence that personal beliefs can have on one's perception of climate change threats (Lawson et al., 2019). This also leads to the suggestion that when introducing these topics to any audience, careful consideration must be taken to incorporate their intrinsic values and beliefs into the lesson.

One of the most important parts of experiential learning is the effect it has on a student's feeling of belonging and identity (Kolb and Kolb, 2009). In my study, students who were enrolled for longer periods of time felt more like they belonged in science and that they identified as a scientist, which is extremely encouraging as a student's positive relationship with science can encourage them to continue their scientific pursuits (Carlone and Johnson, 2007). Research has shown that first-generation college students and underrepresented minority groups that traditionally have a harder time developing their science identity could benefit greatly from participating in experiential learning (Linn et al., 2015; Jackson et al., 2016). Unfortunately, this study did not have a large diversity in ethnic groups, but it provides further evidence that both outreach and UREs can assist students in developing their scientific identity and sense of belonging with time and effort.

Limitations and Future Directions

While the use of alumni provides valuable insight in understanding the lasting impacts an undergraduate creative inquiry may have on student success, it can be difficult to attribute success metrics to the creative inquiry alone. The inability to specifically connect gains to the program is a particular problem in these creative inquiry teams as students may come in with a wide range of previous knowledge about marine science and climate change. While I attempted to control for factors such as ideology, age, and gender, it cannot be ignored that I did find some evidence of the effect that both age and ideology had on gains. These findings were particularly true for variables such as threat perception, where ideology was significant regardless of the independent variable. My small sample size could also have resulted in having low power to detect an effect or possibly inflate some effect sizes. I encourage scholars to replicate the research using appropriate sample sizes driven by an a-priori power analysis to help better understand the effects of UREs and outreach programs on undergraduates. Because many students indicated that they felt positively about the program, those who felt negatively may have disregarded survey requests. Therefore, I must consider that the results of this study may not be representative of all alumni experiences. Future studies should focus on using pre- and post-enrollment surveys to evaluate true quantitative gains throughout the course of the programs. As of Fall of 2021, the pre and post surveys were implemented in the outreach creative inquiry. I plan to continue monitoring the program through periodic alumni surveys. Control groups are also a general source of contention in these types of studies (Kardash, 2000). It can be especially difficult to find a comparable group to that of outreach or research programs as these are normally competitive programs, or programs that focus on unique concepts outside of the normal curriculum. Future research should consider comparing these types of programs against those enrolled in a traditional lecture-style course on the subject. Finally, while the study demographics were overall comparable to the university and majors that participated in the program, these demographics are not necessarily reflective of other institutions or their departments. Therefore, careful consideration should be taken in extrapolating these findings to departments which may have a greater diversity of participants. I am currently exploring options to diversify the program in a meaningful way.

Conclusion

My study contributes to the growing body of literature suggesting the impact that experiential learning can have on student knowledge, careers, and attitudes. Although the creative inquiry teams were vastly different in their approaches, the message across them both were the same: ocean conservation is important. Both exemplified using experiential learning to engage students within this important topic. While I initially sought to look comparatively at gains across both research and outreach teams, these findings suggest that both forms of experiential learning can be used as a tool to increase perceived knowledge, communication skills, conservation desire, and lead to a higher sense of science identity and belonging. As shown in this study, educators interested in integrating experiential learning into their curriculum should consider creating long-term opportunities for their students while providing open collaboration with mentors. Employers of experiential learning should also account for student values and experiences such as ideology, when designing a research or outreach program. Although limitations such as funding, time, and faculty/graduate student involvement can inhibit the integration of experiential learning, this study shows the importance of experiential learning on undergraduate success. The study also provides evidence for experiential learning to combat deficits in climate change and ocean literacy knowledge. I encourage the continued use of such techniques to simultaneously contribute to young adult's understanding of climate change while allowing them opportunities to combat it through research and outreach.

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CHAPTER THREE
PROJECTS ARE NOT JUST FOR KIDS: INTEGRATING SCIENCE OUTREACH PROJECTS INTO UNDERGRADUATE LEARNING DURING A PANDEMIC

Introduction

In 2020 the world experienced a shift unlike any in the past century: the impact of the COVID-19 pandemic. The reach of the pandemic was vast, affecting the lives of many, especially those on both the student and instructor sides of education (Müller et al., 2021). As a matter of public safety, many institutions switched from in-person teaching to fully online teaching requiring a dramatic change in the delivery of course content. While publications outlining and measuring the overall impact are still ongoing, studies thus far show a sharp decline in student motivation, engagement, and academic achievement (Daniels et al., 2021; Humphrey and Wiles, 2021). Notably, these impacts took hold at many universities worldwide. For example, a study by Aristovnik et al. (2020) found that students experienced severe mental distress and anxiety caused by the pandemic. Outside of stress related to academic achievement, undergraduates struggled to find a sense of community, typically obtained through in-person courses (and experiential courses) (Gamage et al., 2020; Tan, 2021). Due to the impact of this pandemic and the switch to online education, higher educators globally are advocating for revised curricula that provide engaging lessons to maintain student motivation, provide opportunities for skill development, and provide community experiences (Gamage et al. 2020; Humphrey and Wiles, 2021). One avenue for accomplishing these goals is through the implementation of inventive lessons, such as Project-Based Learning (PBL).

Project-Based Learning

PBL is an open-ended, inquiry-based approach to course content consisting of five parts, (1) open ended inquiry, (2) collaborative groupwork, (3) technology, (4) formative assessments, and (5) a tangible product (Krajcik and Blumenfield, 2006). To be considered PBL, the curriculum should incorporate all five of these components (Figure 3.1A). PBL is often difficult to implement in traditional, in-person courses due to funding, time, and resources (Blumenfield et al., 1991; Bilgin et al., 2015). Other issues preventing teachers from adopting PBL include caps on class sizes and administrative interference (Blumenfield et al., 1991). However, student gains from PBL can be extremely valuable to teachers willing to work through these complications. Due to the collaborative nature of PBL, students often form a peer learning community based on support and feedback cycles (Barron et al., 1998). These communities can increase student motivation, engagement, and feelings of belonging within the classroom and subject area (Bilgin et al., 2015). These gains are compounded by the tangible product created at the end of the project. Because projects are often reviewed and critiqued through formative assessments, participants can reflect on their knowledge and build on the wisdom of others (Blumenfield et al., 1991; Chanpet et al., 2020). Students involved in PBL can also deepen their understanding of scientific inquiry and processes while promoting conceptual understanding (Schneider et al. 2002). A review by Guo et al. (2020) summarizes these gains into cognitive outcomes (knowledge and strategies), affective outcomes (student-perceived gains, science identity and belonging, and general feelings about PBL), and behavioral outcomes (skills and engagement). Gains afforded by PBL provide a great opportunity when combined with inquiry-based classes where active learning is encouraged (Barron et al., 1998). This combination can increase deeper-level critical thinking in a science context while increasing student motivation, self-efficacy, and skills such as science communication through group work (Schneider et al., 2002; Young and Legister, 2009). Additionally, inventive, exploratory forms of active learning like PBL allow students to develop deeper cognitive processes and schema (Schwartz and Martin, 2004). Eventually, these gains can be transferred outside the project and into new concepts and courses.

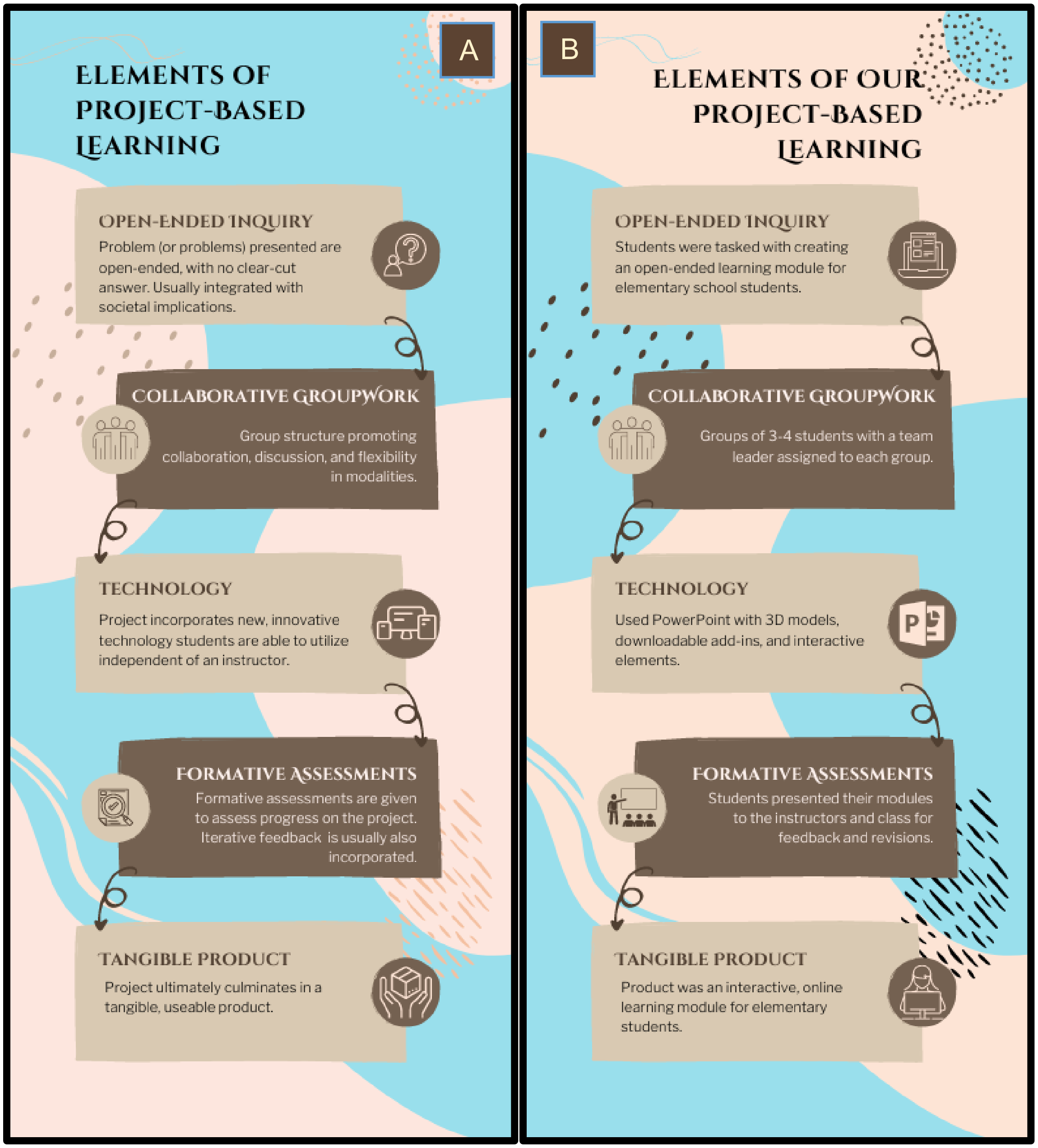


Figure 3.1. Elements of project-based learning and elements of project-based learning from the study. All components must be present to be considered project-based learning.

Project-Based Learning in Marine Science

Studies employing PBL are broad and can range in subjects from the humanities to the sciences. Many studies involving PBL are centered around primary or secondary education, although post-secondary education also integrates it. For instance, engineering departments in university schools use project-based learning in upper-level design projects to provide their students with more practical problem-solving skills (Savage et al., 2007). Science education in the medical field has also been known to integrate PBL into its curriculum through service-learning, increasing empathy among young doctors for their patients (Kim, 2020). Despite the success that PBL has had in undergraduate engineering classes and postgraduate biology courses, its efficacy in many other undergraduate sciences, such as biology, is not well-studied in the literature. This lack of research is also the case for many marine science classes with a PBL-integrated curriculum. Courses found in the literature are based on statistics, phylogenetics, or genomics while only using marine science as a broad subject area (David, 2018).

Other examples include undergraduate research experiences, which often do not incorporate all five elements of PBL (Sims et al., 2021). Marine science courses arguably stand to gain the most from PBL due to the intersecting goals of increasing conceptual understanding, changing attitudes, and enhancing specific skills required in applied marine conservation (Wharton et al., 2019; Ward and Cowie, 2019). These intersections are especially prevalent in marine science communication or outreach, requiring students to understand the basics of marine science while effectively communicating the current ocean health and climate change crisis (Sims et al., 2021; Tallapragada et al., 2021).

Online Project-Based Learning

Another area of limited exploration in PBL is its use in online courses. Due to the nature of online learning, there are alternative considerations for a PBL approach. Limitations related to project funding and administrative interference may be effectively eliminated from the approach, creating opportunities for larger-scale digital projects and minor hindrances from upper-level administration (Chanpet et al., 2020). However, these benefits may be marginal compared to the costs of eliminating face-to-face group work and tangible final products, two of the five critical components of PBL. Previous studies have shown that online PBL can promote collaboration among students when used correctly and increase conceptual understanding while developing schema (Lou and MacGregor, 2004; Thomas and MacGregor, 2005; Koh et al., 2010).

Additionally, online learning allows for constant learner reflection due to the written record of communication and developed artifacts (Chanpet et al., 2020). A study that interviewed high school teachers who implemented online PBL in their classrooms also found that PBL helped increase students' motivation while providing opportunities for student connections and unique educational experiences (Hira and Anderson, 2021). Alternatively, if implemented poorly and without consideration for student needs (such as online learning), students that engage with PBL could experience cognitive overload (Blumenfield et al. 1991). This overload can lead to frustration toward the general assignment, an already critical consideration in PBL (Sweller, 1988). Project design considerations can be especially essential to educators in science fields where online learning is less common, and PBL is scarcely considered.

My Institution

My institution, Clemson University, is one such example of a traditional, primarily undergraduate-focused university forced to close its doors to in-person instruction and pivot to online platform instruction during the 2020-2021 academic year. Clemson University is home to an inquiry-based undergraduate learning initiative called creative inquiry (CI). Students in the CI program can participate in various research or outreach-based projects ranging from the humanities to the sciences. All participants earn course credits for their involvement in a CI team and are allowed to continue the course for multiple semesters or change CI teams to fit their interests. During the COVID pandemic, these CI courses primarily moved online to accommodate students and university policies. In my creative inquiry team, this change in course modality and loss of public outreach opportunities severely limited the original goals of my marine science outreach class. Traditionally, students in this CI interacted directly with elementary students through a set of in-person marine science exhibits. Through this Science, Technology, Engineering, Arts and Mathematics (STEAM) outreach program, undergraduates gained confidence in their knowledge of marine science, solidified their career paths, and altered their attitudes about ocean health and conservation while helping elementary students to learn about the ocean environment (Sims et al., 2021; Tallapragada et al., 2021). However, due to the loss of this public outreach program, students could no longer directly interact with elementary students. Instead, I altered the CI course curriculum to incorporate an innovative, PBL approach that would indirectly connect undergraduates, marine science, and elementary students through tangible online learning modules.

Hypotheses

Through this redesigned CI course, my goal was to assess the benefits of marine science integrated PBL for undergraduates through an online platform while continuing my outreach efforts for elementary students. For this PBL study, my research questions are: (1) Do undergraduates engaged in project-based learning centered in marine science enhance their understanding of basic marine science concepts related to ocean literacy principles? (2) How does this project-based learning course alter student attitudes towards conservation-focused behaviors and feelings of belonging in science? (3) Do undergraduates who participated in creating online learning modules through project-based learning feel more confident in their communication and education-based skills?

Methods

Demographics

Approximately thirty-two surveys were collected over two semesters, resulting in 28 useable surveys after discarding responses that failed attention checks. Demographic information of the genders, ethnicities, and majors of participants are given in Table 3.1. The average age of students was 21, with a range of 19-23.

Table 3.1. Demographics of all participating students reported in percentages.

Gender	
Response	**% of Participants**
Male	18%
Female	79%
Preferred not to Disclose	3%
Ethnicity	
Response	**% of Participants**
White/Caucasian	88%
American Indian or Alaskan Native	3%
Asian	6%
Hispanic/Latinx	3%
Majors	
Response	**% of Participants**
STEM	79%
Humanities and Social Sciences	21%

Project-Based Learning Approach

Students who elected to take part in this CI course did so exclusively online for one or two semesters. All students met weekly for two hours synchronously over Zoom throughout this study. For the first four weeks of each semester, all undergraduates were taught the basics of climate science, ocean conservation, marine ecology, pedagogical practices, and storytelling/module development in an online format using the Zoom platform. These materials were taught in an active-learning format with a mix of lecture and discussion-based material. Specifically, this pre-learning introductory period was structured to be prior scaffolding for student understanding – similar to other PBL studies (David, 2018; Savage et al., 2007). After these four weeks, students were introduced to the PBL assignment expectations (Figure 3.1B). This approach first involved splitting students into assigned groups of three with one team leader. Team leaders were students who were enrolled for at least one prior semester (the first semester's team leaders were a part of the in-person course, the second semester's team leaders were a mix of those who had experienced the in-person or online course). These teams were constructed based on major, with a distribution of majors on each team. Each group was then tasked with creating an online learning module based on a problem-based approach for elementary students (see Figure 3.1B).

Additionally, all teams were required to center their modules on an assigned ecological theme and ocean literacy principle and given a loose rubric to follow (Tables B-1 & B-2). The teams created these learning modules over five weeks, with the final week culminating in a virtual presentation to the entire class. Team leaders also developed lesson plans that would accompany the online learning modules. After presenting their marine science module, teams began a new learning module centered around a new ocean literacy principle and ecological theme.

Data Sources

To assess changes in student conceptual understanding, communication skills, and self-efficacy before and after participating in project-based learning, all undergraduate students were asked to take a Qualtrics survey at the immediate start and end of the semester. The survey included questions based on four main components: demographics, knowledge, skills, and attitudes (Table 3.2). Questions were selected based on previous studies used to assess these three dependent variables (Sims et al., 2021). Upon survey completion, pre and post answers were paired anonymously through codes entered in the course's online learning platform. These survey questions were approved by the Clemson University Institutional Review Board (IRB2018-497).

Variables

All variables and their relation to each hypothesis are given in Table 3.2. Composite variables were created by combining answers to those questions that addressed the same domain and were tested for consistency with Cronbach's alpha (Tavakol and Dennick, 2011). Multiple survey questions with high consistency (those with Cronbach's alpha scores over 0.70 or in the case of two variables, a significant correlation) were considered reliable and combined into a single composite variable.

Table 3.2. Survey metrics used for conceptual understanding. These metrics were asked in both pre and post-surveys. Combined metrics with more than two variables are indicated with Cronbach's alpha scores under survey measures. Combined metrics with two variables are indicated with p-values obtained from Pearson's product-moment correlation.

Knowledge
Conceptual Understanding (1 = Definitely False; 4 = Definitely True)
Which of the following sentences are true? The Earth has on big ocean with many features The Earth has always had an ocean The ocean is a major influence on weather and climate The ocean makes the Earth hotter* All life arose in the oceans The ocean and humans are interconnected The ocean is largely unexplored
Perceived Knowledge (1 = Nothing at all; 5 = A great deal (expert-level)
How much do you know about marine science?
Attitudes
Importance of Marine Science (1 = Not at all important; 5 = Extremely important)
Please indicate how important marine science is to you
Threat (1 = No threat at all; 4 = Very high threat)
What level of threat does each of the following topics pose to ocean health? Ocean warming Plastic (or other trash) pollution and debris Ocean acidification (lower pH) Loss of endangered species Nutrient pollution (eutrophication) Overfishing Habitat Loss Disease and pathogens Pre-test Cronbach’s alpha = 0.81; Post-test Cronbach’s alpha = 0.78
Belonging (1 = Strongly disagree; 5 = Strongly agree)
Please indicate your level of agreement with the following statements: I have a strong sense of belonging in the science community I derive great personal satisfaction from working on a team that is doing important scientific work such as this CI I have come to think of myself as a science student I feel like I belong in the field of science The work of a science student is appealing to me It is important to take part in science communication activities with non-science majors

I have a duty as a student to take part in science communication activities targeting the general public including children Pre-test Cronbach's alpha = 0.72; Post-test Cronbach's alpha = 0.84
Skills
Communication (1 = Strongly Disagree; 5 = Strongly Agree)
Please indicate your level of agreement with the following statements: I am confident in my ability to communicate about marine science to my friends and family
Ocean Stewardship (1 = Strongly Disagree; 5 = Strongly Agree)
Please indicate your level of agreement with the following statements: I am confident that I can engage in stewardship behaviors to help the oceans
Resources (1 = Strongly Disagree; 5 = Strongly Agree)
Please indicate your level of agreement with the following statements: I am confident that I can find resources to help me keep up with learning more about marine science
Learning Module Development (1 = Strongly Disagree; 5 = Strongly Agree)
Please indicate your level of agreement with the following statements: I am confident in designing an online learning experience revolving around ocean literacy I am confident in helping children use digital platforms to learn about oceans Pre-test p-value = <0.0001; Post-test p-value = 0.0012
Lesson Plan Development (1 = Not at all confident; 4 = Very confident)
For each of the following statements, please rate the level of confidence you feel in adopting the approach for a lesson plan centered around the following themes: Anthropogenic - How humans are affected by changes in the ocean Keystone - How keystone species are affected by changes in the ocean Foundation - How foundation species are affected by changes in the ocean Charismatic - How charismatic species are affected by changes in the ocean Marine science in general Pre-test Cronbach's alpha = 0.86; Post-test Cronbach's alpha = 0.89

*Reverse coded (statement is false)

Analysis methodology

All analyses were completed using R (version 1.4.1717). Student surveys that failed attention check questions were excluded from the dataset (N = 4). Results were tested for normality using Shapiro-Wilks tests (Kim, 2015). Paired sample t-tests were used for normally distributed data (Cooper et al., 2020). Non-normally distributed data were compared using paired sample Wilcoxon Signed-Rank Tests (Kim, 2015).

Results

Conceptual Understanding

Conceptual understanding of ocean literacy and marine science was measured using two composite variables, conceptual understanding and perceived understanding (Table 3.3). Conceptual understanding of ocean literacy principles significantly increased after students participated in PBL ($p = 0.0006$, $V = 20$) (Figure 3.2A). Similarly, students significantly increased their perceived knowledge of marine science ($p = 0.0002$, $V = 0$) (Figure 3.2B).

Table 3.3. Independent variables measured for each of the three hypotheses. Variables were non-normally distributed and tested with Wilcoxon Signed-Rank Tests. Significant variables are displayed in **bold**.

Conceptual Understanding		
Measured Value	**p**	**V**
Objective Knowledge	**0.0006**	20
Perceived Knowledge	**0.0002**	0
Attitudes		
Measured Value	**p**	**V**
Importance of Marine Science	0.2755	13.5
Threats to the Marine Environment	0.2755	296.5
Belonging in Science	0.4415	46
Skill Development		
Measured Value	**p**	**V**
Communication Skills	**0.0132**	12
Stewardship Skills	**0.0364**	3
Module Development Skills	**0.0061**	27.5
Lesson Plan Development Skills	**<0.0001**	6.5
Science Resource Skills	0.0953	9

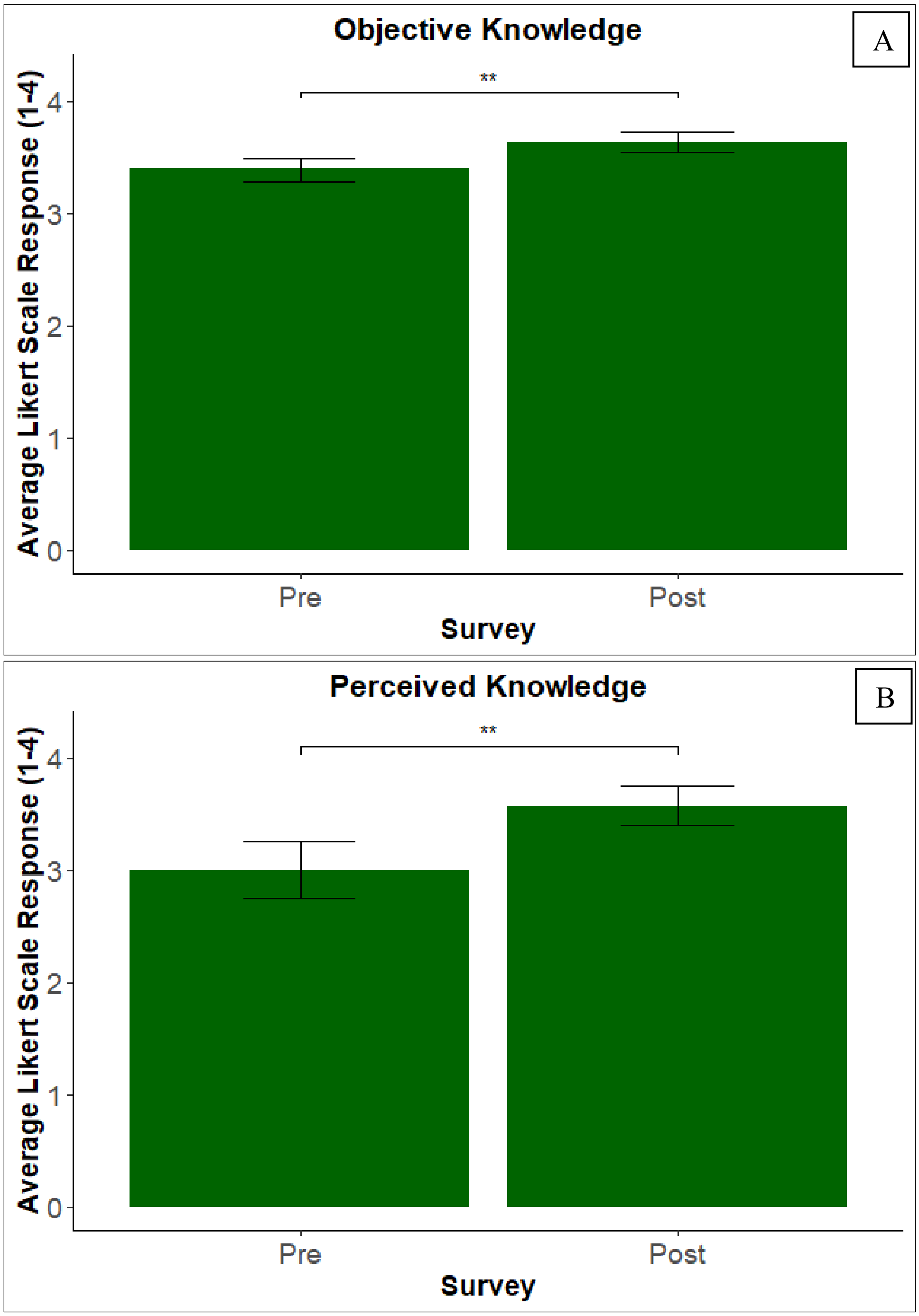
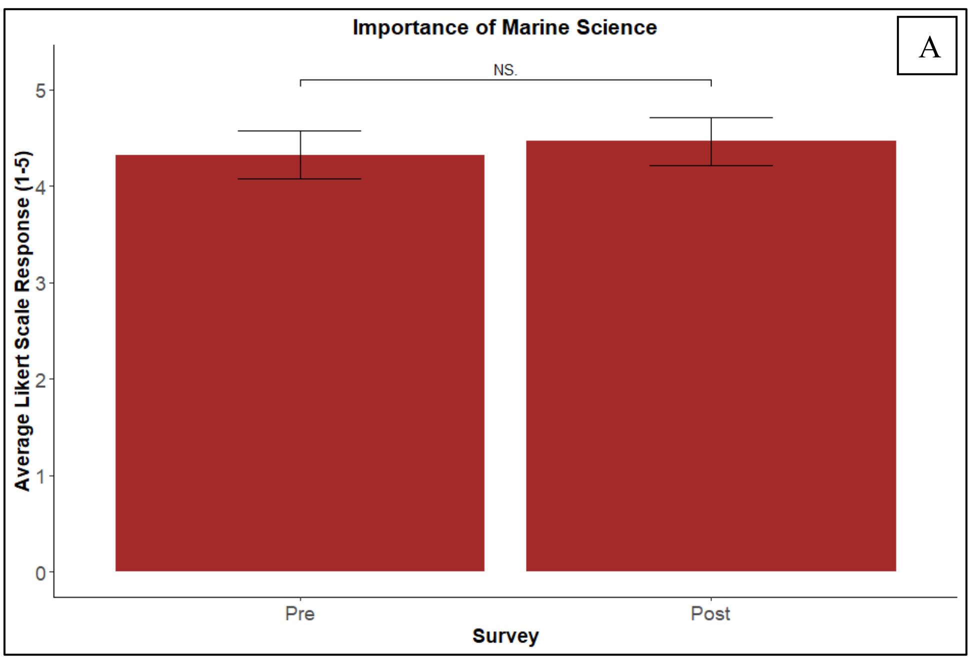


Figure 3.2. Pre to post scores related to conceptual understanding (knowledge). Maximum scores for all values are listed on the y-axis. Significance is indicated by asterisks (*$p < 0.05$, **$p < 0.001$, ***$p < 0.0001$, N.S. $p > 0.05$).

Conservation Attitudes

Students were asked how important marine science was to them to assess student attitudes towards marine science (Table 3.3). There were no significant differences in importance before and after participation in PBL (Figure 3.3A). Similarly, students did not exhibit significant increases in feelings of science belonging or threats towards the marine environment (Figures 3.3B & 3.3C). However, attitudes towards threats to the marine environment were extremely high from the project's onset (M = 3.81, sd = 0.26, Scale Range = 1-4). This was also true for feelings of belonging in science (M = 4.75, sd = 0.29, Scale Range = 1-5).



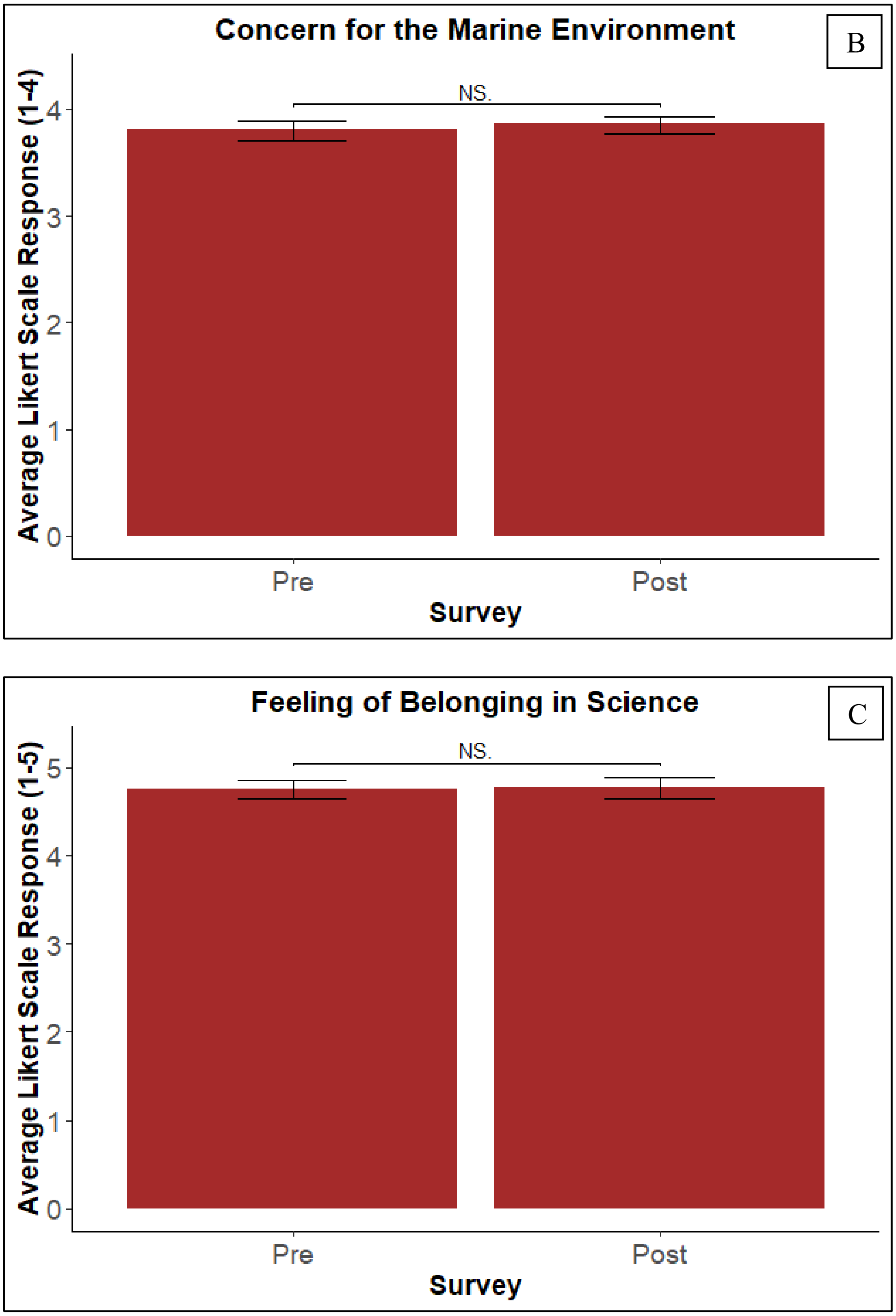
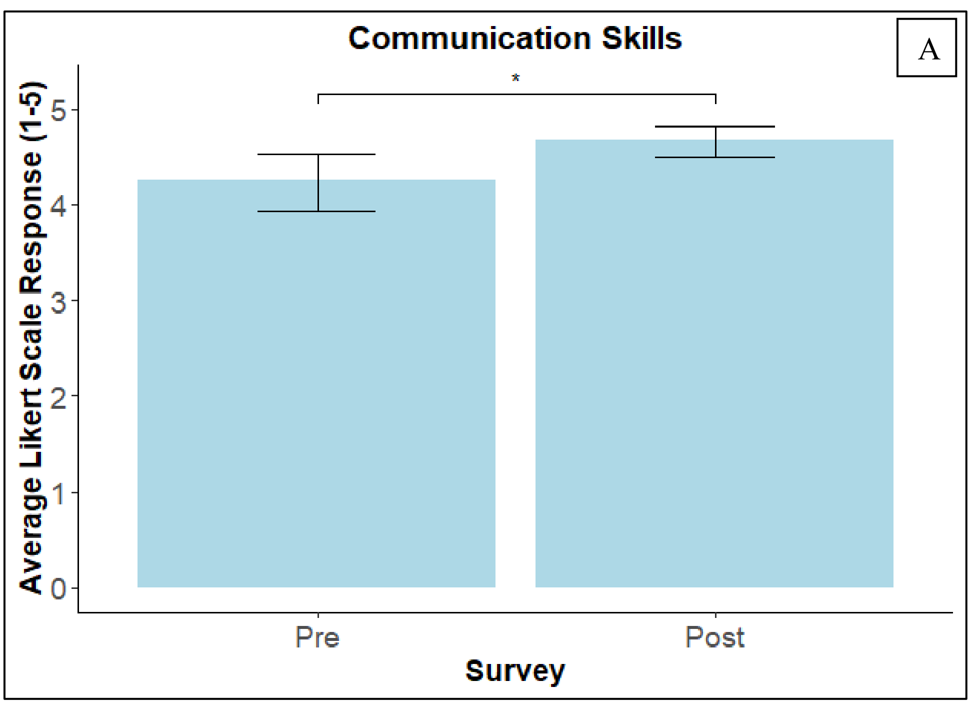
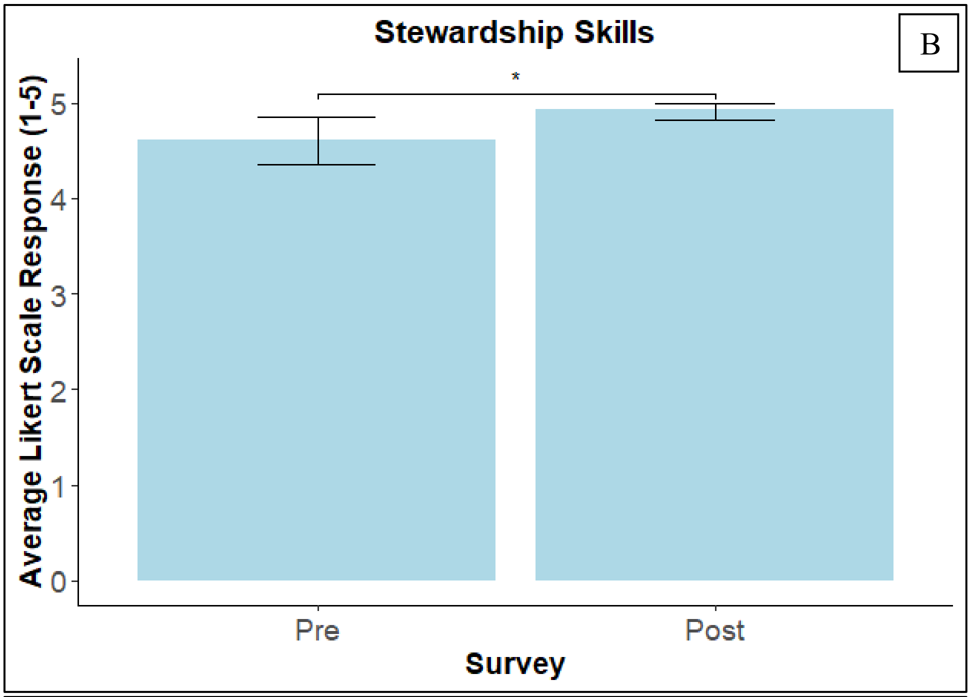


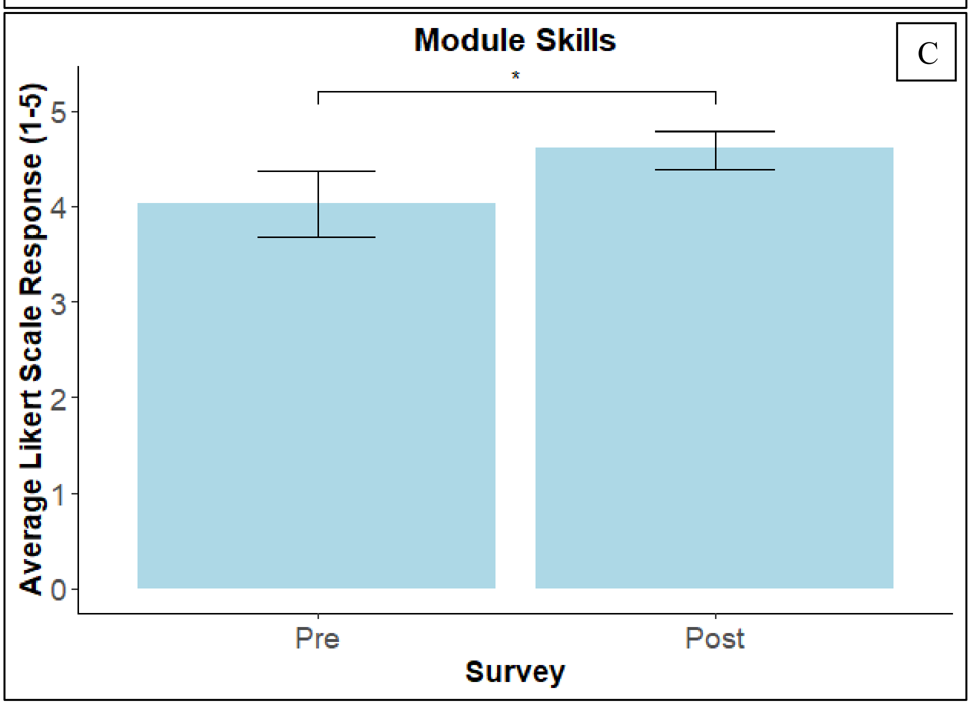
Figure 3.3. Pre to post scores related to attitudes. Maximum scores for all values are listed on the y-axis. Significance is indicated by asterisks (*$p < 0.05$, **$p < 0.001$, ***$p < 0.0001$, N.S. $p > 0.05$).

Skill Development

To assess the gains in confidence for a range of skills, students were asked to reflect on their degree of confidence regarding skills in communication, stewardship, module development, lesson plan development, and identification of science resources (Table 3.3). Communication and stewardship skills increased among students after participating in PBL ($p = 0.0132$, $V = 12$; $p = 0.0364$, $V = 3$) (Figures 3.4A and 3.4B). Students indicated a significantly higher confidence in developing online learning modules after participating in PBL ($p = 0.0061$, $V = 27.5$) (Figure 3.4C). Additionally, students were significantly more confident in developing lesson plans after participation ($p < 0.0001$, $V = 6.5$) (Figure 3.4D). There was no significant difference in students' ability to obtain scientific resources in marine science after participating in the study ($p = 0.0953$, $V = 9$) (Figure 3.4E).




Stewardship Skills
B
*
Average Likert Scale Response (1-5)
0
1
2
3
4
5
Pre
Post
Survey


Module Skills
C
*
Average Likert Scale Response (1-5)
0
1
2
3
4
5
Pre
Post
Survey

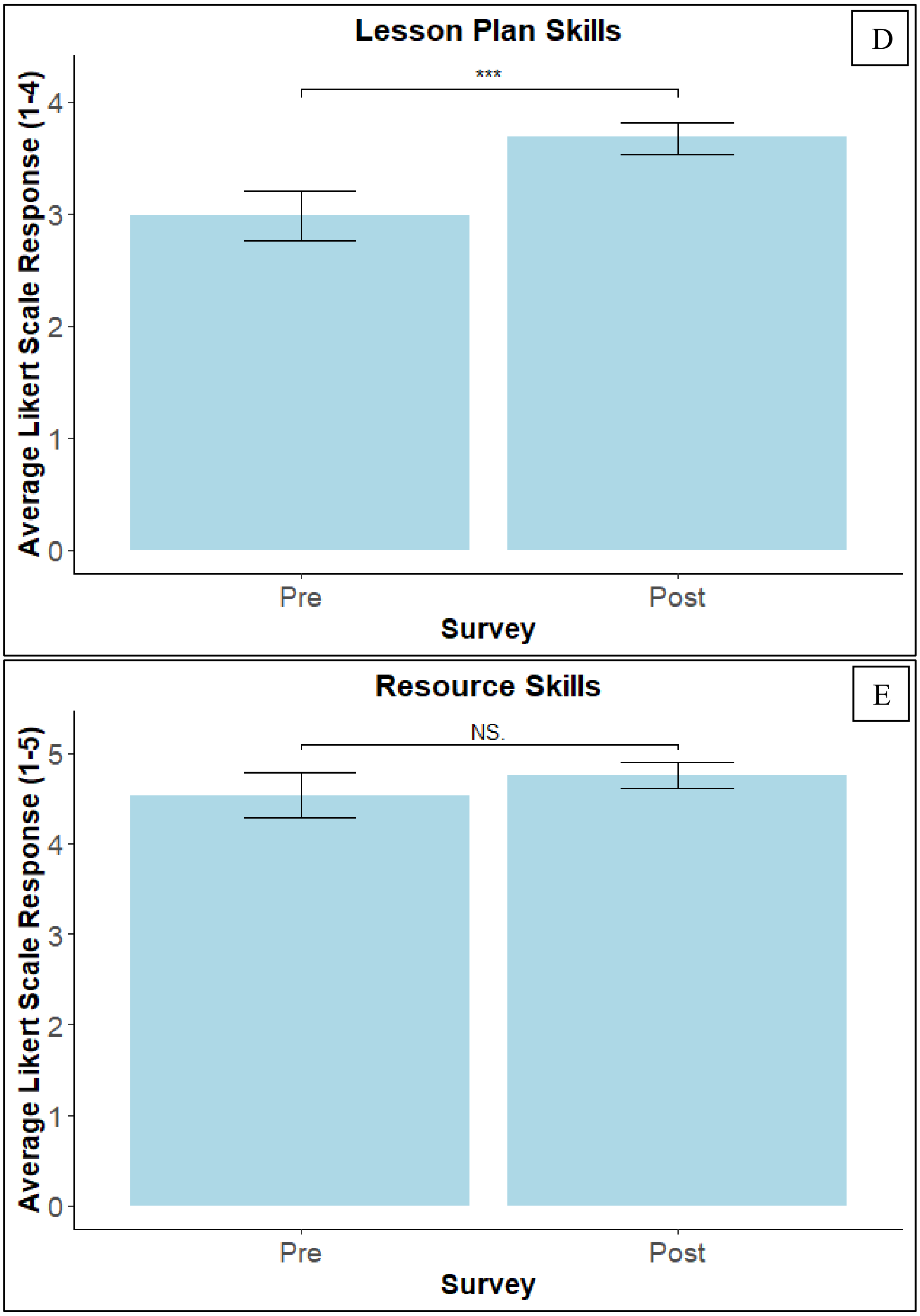


Figure 3.4. Pre to post scores related to skills. Maximum scores for values are listed on the y-axis. Significance is indicated by asterisks (*$p < 0.05$, **$p < 0.001$, ***$p < 0.0001$, N.S. $p > 0.05$).

Discussion

This study aimed to understand the effects of integrating PBL into an online undergraduate outreach course. These results led me to conclude (1) Our course, featuring online project-based learning centered on marine science has the potential to enhance undergraduate understanding of basic marine science concepts related to ocean literacy principles and their perception of their marine science knowledge. (2) This project-based learning course did not alter student attitudes towards conservation-focused behaviors. (3) Undergraduates who participated in creating online learning modules through project-based learning overall felt more confident in their communication and education-based skills. However, their confidence in obtaining scientific resources did not change.

My study showed that students experienced significant increases in conceptual understanding after participating in this PBL course, which modeled other in-person PBL approaches, which show that students can increase their conceptual understanding through PBL (David, 2018). Because of the nature of PBL as a collaboration-based, inventive learning format, understanding usually goes deeper than pure memorization or conceptual understanding. Arguably the more important outcome of this study was the increase students had in their confidence of their own understanding. Previous studies have shown that inventive learning such as PBL can increase this confidence, later leading to a deeper conceptual understanding of subsequent topics – even in areas outside of the PBL study topic (Schwartz and Martin, 2004). It can also increase a students' ability to self-regulate their learning (Lin, 2018).

Additionally, the collaborative nature of PBL allows for cyclical feedback between students, where groups can formulate new ideas while allowing for corrections (Barron et al., 1998; Krajcik, 2015; Lin, 2018). These implications are significant in the case of this course, where students voluntarily enroll and are looking to apply the knowledge they gain in subsequent classes. Even greater considerations for PBL are in the online aspects of this course. While many studies have shown that students feel they have no conceptual gains through online, traditional learning styles (such as lecture-based), my analysis suggests that the online format did not negatively impact the effect of PBL on undergraduate understanding (Daniels et al., 2021; Tan, 2021). Thus, PBL may have the ability to combat any negative impacts of online learning formats through conceptual gains and should be studied using an appropriate control of a non-PBL online format to determine if this active learning component of online courses has significant gains over traditional lecture-based online courses.

In addition to conceptual gains, students experienced significant skill gains in science communication, education, and stewardship. These increases echo the importance of PBL seen in other studies on skill development (Bilgin et al., 2015). Because engagement with technology and open-ended problem solving are foundational elements of PBL, students often develop more significant technology expertise and utilize resources (ChanLin, 2008). For students in this course, their expectation of creating an online learning module for elementary students intersected skills in technology, communication, and education. Since most of my students came from STEM (Science, Technology, Engineering, and Mathematics) disciplines, they began with limited expertise in communication and education (as evidenced by their pre-tests in these skill areas). Educators may face exceptional difficulties in assisting undergraduates in developing these critical skills in traditional science courses, particularly when online (Spektor-Levy et al., 2009). However, when integrating science and service-style learning (such as building online learning modules for elementary students), skills such as these can become significant outcomes of PBL (Kim, 2020). In the case of my study, these skill increases in education and communication skills may provide evidence for the strengths of PBL in promoting student gains outside of simple conceptual understanding.

While many of my results show improvement before and after participating in PBL, attitude pre-assessments showed that students began with strong motivations towards protecting the marine environment, marine science, and their belonging in science. In this case, I believe that I did not see significant changes in student attitudes due to their initially high scores at the beginning of the assessment. Although this may be considered a limitation of the study due to non-randomized student distributions, these findings have some important implications. Motivation has always been considered one of the primary underlying factors for student persistence and ability to deeply connect with concepts, especially in PBL (Blumenfield et al., 1991; Mayer, 1998; Keller, 2008). However, the interconnectivity between motivation and relevance means it can be relatively complex for students who do not feel strongly connected to the material to become motivated (Keller, 2008). When student motivation, goals, and interests are not considered in open-ended, inventive learning such as PBL, it can lead students to feel overwhelmed, disheartened, and apathetic towards a project (Helle et al., 2006; Savage et al., 2007; Daniels et al., 2021). In the case of online learning, previous studies have struggled to motivate their students to participate in learning activities (Tan, 2021). Many studies have even cited decreases in student motivation and engagement over the course length (Daniels et al., 2021; Humphrey and Wiles, 2021). In my case, students who joined this course were entirely motivated to participate in a class based around marine science outreach, although the expectation was an in-person course. However, students remained motivated throughout the course despite the unexpected transition to online learning. While the results of this study cannot necessarily claim that PBL was the reason for this consistency in motivation, I believe it to be a factor.

Limitations and Future Directions

Perhaps the most obvious limitation of this study is the lack of a control group. Because this was not a comparative analysis, it is difficult to point to PBL solely as the underlying reason for increases seen through this study. My reasonings for this decision were due to the course's size and ethical concerns. The first was the lack of a valid, comparative sample. Because this course lends itself to small class sizes, I did not have the option of splitting the class into an experiential form of learning like PBL versus a pure lecture style. Doing so would have severe implications for sample sizes statistically. Additionally, randomly selecting students in my voluntary group to participate in lecture-style learning versus experiential (like PBL) could create ethical concerns within my university due to the experiential foundation of the course. Because PBL has been well-established as a practical learning style in literature, I did not believe this warranted a comparative analysis (Schneider et al., 2002; Helle et al., 2006; Merritt et al., 2017). Additionally, other studies have modeled similar approaches, gauging which aspects of PBL most effect specific outcomes rather than if PBL is effective overall. For instance, Bilgin et al. (2005) found that students who worked collaboratively in their groups exhibited more positive feelings towards groupwork and stronger gains in conceptual understanding. Thomas and MacGregor (2005) found similar gains from collaborative learning in their online PBL research. However, to specifically understand the role that PBL played in this course, future analysis will focus on qualitative coding of student feedback from focus groups to understand the impact from PBL alone.

The second significant limitation to consider is the non-random distribution of my study group. Although my group reflects Clemson University's demographic distribution throughout participating colleges, this is not necessarily the case for other institutions. As mentioned earlier, I believe that this non-random sampling had a powerful impact on my attitude sections. However, this distribution could have also impacted the skill and conceptual areas. Future studies should look to deepen understanding of student attitudes through qualitative analyses that may better discern authentic insights of student attitude changes due to online PBL. This form of analysis could be particularly critical in PBL with societal implications such as this one.

Conclusions and Implications

My study provides evidence that PBL can be an effective avenue for online education, specifically situated in marine science. While studies have shown evidence for PBL effectiveness in online environments, this study is the first to combine informal learning through outreach efforts with an online, science-based PBL. The findings suggest that courses such as this can provide students with significant conceptual understanding and skill development. Despite the pandemic's impact on in-person instruction, this may not necessarily mean that instructors are left without engaging, practical tools in their classroom. Hopefully, with the integration of motivational learning techniques such as PBL, students, even in online settings, can remain connected in their courses and continue to develop a deeper, more meaningful understanding of concepts.

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CHAPTER FOUR
FUN WITH CITIZEN SCIENCE: A COMPARATIVE ANALYSIS ON THE EFFECTS OF VIRTUAL REALITY AND CITIZEN SCIENCE ON ELEMENTARY STUDENT SCIENCE IDENTITY AND CONCEPTUAL UNDERSTANDING OF OCEAN HEALTH AND CLIMATE CHANGE

Introduction

Ocean health and climate change have become two of the most pressing issues of the twentieth century. Effects of these two concerns, such as tropical storms, flooding events, ocean acidification, and droughts, are having extreme impacts on populations throughout the world (Padhy et al., 2015; Pinnegar et al., 2019; Duarte et al., 2020). Children are undoubtedly some of the most vulnerable groups to these effects (Clayton et al., 2017; Sanson et al., 2019). However, many are unaware of the factors underlying them (Lambert et al., 2012). While some of the miscommunication around climate change and ocean heath can begin at home, much of this can be attributed to the absence of climate change and ocean health standards within modern public-school curricula (Plankis and Marrero, 2010; Corner et al., 2015; Valdez et al., 2018; Gough, 2017). This lack of understanding is compounded by a disconnection from science, which can begin in elementary schools and persist into high school and beyond (Archer et al., 2010). Additionally, female students and those that identify as part of an underrepresented minority group may find themselves even more disconnected from science as they grow older due to stereotypes and barriers to entry into STEM fields (Miyake et al., 2010; Macphee et al., 2013; Williams and George-Jackson, 2014; Jackson et al., 2016; Starr, 2018). Eventually, this can lead many women and underrepresented minority students to shy away from the scientific process (Jackson et al., 2016). Because some students draw back from science, they often do not understand how to combat underlying causes, leading to feelings of fear, frustration, and angst (Ojala, 2015; Stevenson and Peterson, 2016; Clayton et al., 2017). However, when students engage in climate change or ocean health mitigation through conservation, these feelings are often quelled, and students are inspired to action (Stevenson and Peterson, 2016). Thus, many educators are leaning on informal education to substitute for formal teachings about climate change and ocean health, promoting understanding and connections to these two topics.

Informal education has often been used to increase student understanding of undertaught but societally relevant concepts such as climate change (Jacobson et al., 2016; Chabanet et al., 2018; Chung and Brown, 2018). In elementary schools, examples of informal interventions can range from educational plays to museum visits (Price and Hein, 1991; Rennie et al., 2003; Davidson and Simms, 2017; Tallapragada et al., 2021). Previous studies have cited informal education to increase conceptual understanding and change attitudes and outlooks for young students (Sellmann and Bogner, 2013; Davis, 2018; Dean et al., 2018). While the benefits of informal education for elementary school students are plentiful, facilitators of these programs can have limitations on funding, time, and personnel (Andrews et al., 2005). In the case of researchers, some find that informal outreach education may have a stronger levy of time and effort than reward for their research (Andrews et al., 2005). However, by combining informal education and data collection, the benefits could far outweigh the costs.

Citizen Science Overview

Academics worldwide utilize "citizen science" to connect research and outreach through experiential learning. Citizen science involves a mutualistic relationship where principal investigators employ the public to collect data or use methods that would otherwise be difficult or impossible for the investigative team to obtain (Bonney et al., 2009). Through this, academics receive crucial scientific data while allowing public members to become invested in scientific research. The use of citizen science has increased substantially over the years, despite concerns over data reliability and ownership (Gadermaier et al., 2018; Jiménez et al., 2019). This expansion has arguably had the most influence on biological sciences especially conservation biology and marine sciences (Jefferson et al., 2015; Ellwood et al., 2017; Gadermaier et al., 2018).

In marine science, citizen science connects SCUBA divers to reef conservation through experiential learning. One study conducted by Hesley et al. (2017) on the Rescue a Reef program highlights the use of citizen science to combat current issues within coral biology, reef conservation, and marine ecology fields concurrently. Throughout this program, public participants on SCUBA transplanted endangered coral fragments to conserve reefs degraded by climate change. Before the transplantation effort, all participants viewed a fifteen-minute lecture on coral biology and reef conservation and were trained on coral species and coral stressor identification. Hesley et al.'s study found that participants had a more robust understanding of reef conservation and coral ecology and were also as effective at conducting coral transplants as experts in the program. Their findings promote the strength of citizen science as both an outreach and research tool in a marine science context.

Impacts of Citizen Science on Elementary Students

One of the most significant impacts of citizen science is subverting politically charged science issues away from social biases and towards science-based understanding (Yoho and Vanmali, 2016). The previously mentioned Rescue a Reef program used coral transplantation to inform divers about the status of degrading reef health, arguably one of the most significant consequences of climate change (Hesley et al., 2017). Review articles such as the ones written by Bonney et al. (2014) pose that citizen science is underutilized as a social tool. They provide evidence that these projects can span cultural and political backgrounds by creating impactful and engaging hypotheses and research questions. This transition to science-based understanding can increase conceptual understanding of complex topics. Kermish-Allen et al. (2019) show these impacts in their program called WeatherBlur. Their study combined learning objectives with their citizen science data collection in framing climate change's effect on the fishing catch in a local island community. K-5 students in the program significantly increased their understanding of natural and earth sciences and their ability to interpret graphs of data.

Citizen science is especially appealing to young scientists who are still developing their identity with science. Science identity can be a driving factor behind one’s association with science, particularly in women and underrepresented minority groups (Malone and Barabino, 2009; Starr, 2018). Because science identity is foundational to students who look to pursue STEM fields, fostering identity is crucial in allowing students to continue forward in STEM education (Trujillo and Tanner, 2014). Additionally, a strong science identity can assist in mitigating negative effects caused by stereotypes (Starr, 2018). Jenkins (2011) expresses the value of integrating stakeholders such as introductory biology students into citizen science to increase their science identity. She posits that because students often disconnect between science and their lives, science eventually becomes unappealing and discouraging. By fostering a cultural connection with science in the manner afforded by citizen science, interests in science can be nurtured. This connection is especially critical for young members of the public who are just beginning to form their scientific identity and science stereotypes, such as elementary school students (Miller et al., 2018).

In the case of climate change, citizen science has been suggested to be a vital tool for opening students to discussions on climate change through data (Yoho and Vanmali, 2016). One study by Groulx et al. (2019) provides evidence through the Value-Belief-Norm theory that citizen science may be able to alter climate change attitudes in individuals. In their study, individuals engaged in citizen science began to accept human impacts as the underlying cause of climate change. Another study by Dean et al. (2018) shows that citizen science can lead to a more substantial acceptance of climate change and a stronger desire to employ conservation behaviors. While many studies show how citizen science can change attitudes related to climate change, few make the connection between climate change and ocean health for elementary students. These connections can foster excitement in students far from the coast who may have never seen the ocean (Dean et al., 2018).

Technology and Citizen Science

Studies have also indicated that by integrating innovative technology, citizen scientists can become even more engaged in research limited by specific skills and training (such as SCUBA diving) (Mazumdar et al., 2018). In the case of marine science, students who live inland can struggle to connect with marine research, leading to limited citizen science opportunities only available through aquariums or freshwater ecosystems (Striner and Preece, 2016). However, through technological platforms such as virtual reality (VR), students can explore environments across the world, including those underwater (McMillan et al., 2017; Bailenson et al., 2018; Markowitz et al., 2018; Duwan et al., 2019). Previous studies like Striner's (2016) StreamBED study have already integrated VR field training into citizen science. Other studies cite the benefits of using VR to "gamify" citizen science projects, making them more fun and integrative for the public (Shannon et al., 2021). Review articles like Mazumdar et al. (2018) suggest implications in the fields of virtual and augmented reality for not only training but also data collection purposes. They suggest that citizen science through VR may be an effective and motivating way for the public to become excited about science while contributing quality data to research projects. In the case of elementary students, VR has special considerations due to potential issues of motion sickness and disorientation and is not often used with these younger students (Adams et al., 2018; Tychsen and Foeller, 2020). Therefore, VR has only been used minimally in elementary schools without connection to citizen science.

This Program

While citizen science has been well-studied in public perceptions research and as a viable method for scientific researchers, it is understudied as an experiential learning platform in connection to ocean health and climate change in elementary school settings (and has never been done through VR) (Jefferson et al., 2015; Yoho and Vanmali, 2016). More importantly, no study to my knowledge has compared the use of citizen science against similar, non-citizen science interventions in elementary schools. This informal marine science outreach program seeks to combine the best of all worlds by integrating citizen science with virtual reality in elementary schools. I present introductory marine science concepts to elementary students through this program, then work alongside them as they count fish in a 360-video shown through VR headsets. After collecting data, students report on their findings and engage with researchers directly as they journey through coral reefs.

Research Questions

This program aims to understand the effect of using citizen science for elementary students by using a comparative analysis between groups of students who collect and engage directly with data through VR to those who simply view 360 videos through the VR headsets. I hope to use this as a platform to increase student understanding of marine science topics and concerns while enhancing their science identity. To assess the effectiveness of this program, I proposed the following research questions: 1) How does student identity influence marine science identity? 2) How does citizen science influence student science identity and scientist perceptions? 3) How does citizen science influence student conceptual understanding and attitudes towards climate change and ocean health?

Methods

Study Group

This research was approved by the Institutional Review Board (IRB2021-0467). The study group consisted of 145 4^{th} and 5^{th} grade elementary students across two elementary schools in upstate South Carolina. These grade levels were chosen due to the constraints caused by VR and the stage in science identity development these students are in (Archer et al., 2010; Tychsen and Foeller, 2020). The largest portion of this sample came from a Title I school (n = 117), with the remainder from a magnet school focused on art (n = 28). Both schools were less than twenty miles apart.

Program Layout

Each class was randomly assigned a treatment of either citizen science or non-citizen science. All groups participated in a virtual reality session, but only the citizen science groups collected data and were referred to as "citizen scientists" throughout the program. At the beginning of the lesson, facilitators gave a short lesson on climate change and its effect on coral reef ecosystems, specifically damselfishes. Facilitators also explained to students that researchers at Clemson University are conducting research on coral reefs to understand the impacts of climate change and changing ocean health on damselfish. Elementary students in the citizen science group were told they were assisting in this project by helping us count damselfish in their headsets; the other group was simply told they would be watching reef fishes in VR. All students were given a quick safety run-down and an introductory lesson on the VR goggles. Students were then outfitted with Class VR goggles by exhibit leaders. Undergraduate students ran the virtual reality (VR) experience alongside a graduate student while graduate students led the activities and assessments. The two graduate students (one black/African American female and one white/Caucasian female) were kept consistent to avoid influencing any student perceptions of a scientist between groups (Thomson et al., 2019).

VR video content consisted of 360 videos taken directly from experimental reef sites in conjunction with a behavioral damselfish experiment. Video content was pre-loaded onto the goggles and corresponded with ID numbers written on the front of the goggles. Citizen science students were given a training video to allow them to acclimate to the VR headset and test their ability to count fish in VR. If students could complete the training video correctly, they moved on to the primary videos. Those in the citizen science group were asked to count the number of damselfish present at the end of the video (on a still final frame), while those in the non-citizen science group only watched the footage. Totals were tallied after the video for use in a marine science research project. At the end of the program, students in both groups were thanked for their work as citizen scientists (this term was introduced to the non-citizen science group post-assessment to limit the discrepancies between groups post-experience). Each iteration of the program lasted approximately one hour with twenty minutes devoted to assessment (ten pre and ten post).

Assessments

At the beginning of the visit, students were given a worksheet first asking them their demographic information related to race, gender, and age. All students were then prompted to draw their perception of a marine scientist based on Chambers' Draw-A-Scientist (DAS) test (1983) and Losh et al.'s iteration related to specific professions (2008) (Figure C-1) (Table 4.1). Because drawings can give substantial insights into identity beliefs and values, DAS was chosen as an indirect platform for assessing changes in perceptions of student science identity (Hawkins, 2002; Mensah and Fleshman, 2017). Drawings were completed in colored pencils given by the program instructors. Students were also asked to describe their drawings below the actual picture to clarify images that may be difficult to interpret (Losh et al., 2008). Elementary students were then given three words on the back of this sheet: climate change, ocean health, and you. Students filled out their own Personal Meaning Map (PMM) with these words, demonstrated by the instructor running the experience (van Winkle and Falk, 2015) (Figure C-2) (Table 4.2). PMMs were chosen to assess changes in conceptual understanding and emotional affects related to climate change and ocean health. All worksheets were filled out by both the citizen science and non-citizen science treatments. Students were given ten minutes before the start of the activities and ten minutes after the activities finished to complete the assessments.

Table 4.1. Coded variables for Draw-A-Scientist assessment. Variables are indicated in **bold** in the left column. Continuous variables are indicated with an asterisk*. Categorical variables have selection options listed below the variables. Brief descriptions of each are given in the right column.

Draw-A-Scientist (DAS)	
Variable	*Description*
Number*	Number of scientists in the drawing.
Gender Male Female Other (Trans; Non-Binary/third gender; Other) None	Gender of the scientist drawn descriptions are used as the primary indicator of gender.
Race White/Caucasian Black/African American Other (American Indian or Alaskan Native; Asian; Native Hawaiian or Pacific Islander; Hispanic/Latinx; Other) Unknown/Undeterminable	Race of the scientist drawn descriptions are used as the primary indicator of race.
Age*	Age of the scientist drawn descriptions are used as the only indicator of age. Undeterminable selection is used if no age is given.
Clothing Field Gear Casual Other (Laboratory; Business; Other) None	Clothing the scientist is wearing, drawings are used as the primary indicator of clothing.
Glasses Yes No	If the scientist was wearing reading glasses, drawings are the primary indicator.
Environment Field Other None	Background of the drawing. Descriptions and drawings are used equally to determine.
Research Objects*	Objects in the drawing related to research
Other Objects*	Other objects in the drawing

Table 4.2. Coded variables for Personal Meaning Map assessment. Variables are indicated in **bold** in the left column. Continuous variables are indicated with an asterisk*. Categorical variables have selection options listed below the variables. Brief descriptions of each are given in the right column.

Personal Meaning Map (PMM)	
Variable	*Description*
Climate Change Words/Phrases*	Number of words/phrases surrounding the CLIMATE CHANGE box
You Words/Phrases*	Number of words/phrases surrounding the YOU box
Ocean Health Words/Phrases*	Number of words/phrases surrounding the OCEAN HEALTH box
Number of Climate Change Related Words/Phrases*	Number of words/phrases actually related to climate change
Number of Ocean Health Related Words/Phrases*	Number of words/phrases actually related to ocean health
Overall Climate Change Affect Positive Neutral Negative	Overall emotion (affect) of words/phrases surrounding the CLIMATE CHANGE box
Overall You Affect Positive Neutral Negative	Overall emotion (affect) of words/phrases surrounding the YOU box (only in relation to program elements)
Overall Ocean Health Affect Positive Neutral Negative	Overall emotion (affect) of words/phrases surrounding the OCEAN HEALTH box
Number of Ocean Literacy Principles Referenced 0 1 2	Number of ocean literacy principles referenced in the words/phrases

After all iterations were complete, worksheets were labeled based on school, teacher, grade, and student. Drawings of scientists pre-and post-session were quantitatively coded for variables related to the drawn scientists and the pictures' background (derived from Chambers' 1983 Draw A Scientist Test) (Table 4.1). Personal meaning maps were quantitatively analyzed for variables related to conceptual understanding and emotional relationships (Jesus-Leibovitz et al., 2017) (Table 4.2). Codebooks were developed based on these criteria and given to undergraduate coders (see Appendix D). This codebook underwent four iterations until consistency was obtained among seven students, and the codebook was found reliable (Krippendorff's alpha ≥ 0.80; http://dfreelon.org/recal/recal3.php). Worksheets were randomly distributed among undergraduate students for coding and coded using this codebook (R Version 1.4.1717 – sample function). All codes were inputted through a Qualtrics survey.

Data Analysis

Data analysis was conducted primarily in SPSS (Version 28.0.1.0), although 3-way contingency tables were assessed through http://vassarstats.net/abc.html. Students were compared for associations between their own ethnicity, gender, and age (supplemented by grade) and their scientists' ethnicity, gender, and age using chi-squared analyses.

The interaction between independent variables: treatment (citizen science/non-citizen science) and pre-post changes, as well as dependent, categorical values (ethnicity, gender, clothing, glasses, environment, ocean literacy principles, climate change affect, you affect, ocean health affect) were assessed through 3-way contingency tables.

Delta variables (post-pre) were calculated for continuous variables (age, regular objects, research objects, total words, climate change word relations, and ocean health word relations). All delta variables were tested for normality using Shapiro-Wilkes tests. Variables were compared using Mann-Whitney U-tests, as none were normally distributed (Kim, 2015).

Results

Demographic Distribution

A total of 145 students participated in the program. This study group was primarily distributed among white/Caucasian (n = 51; 35.2%) and black/African American (n = 35; 24.1%) students with the remaining students identifying as an underrepresented minority group (n = 29; 20.0%) or electing not to identify (n = 30; 20.7%). Most students identified as female (n = 80; 55%) with the remainder either male (n = 62; 43%) or unidentified (n = 3; 2%). Treatment groups were almost evenly distributed with 70 students in the citizen science treatment and 75 students in the non-citizen science treatment.

Student Demographics and Draw-A-Scientist Test (DAS)

Chi-squared tests of independence were performed to understand the relationships between student and drawing demographics. Student ethnicity was directly related to scientist ethnicity X^2 (9, N = 140) = 86.416, p = <.001 (Figure 4.1). Student gender was also directly related to scientist gender X^2 (6, N = 140) = 65.624, p = <.001 (Figure 4.2).

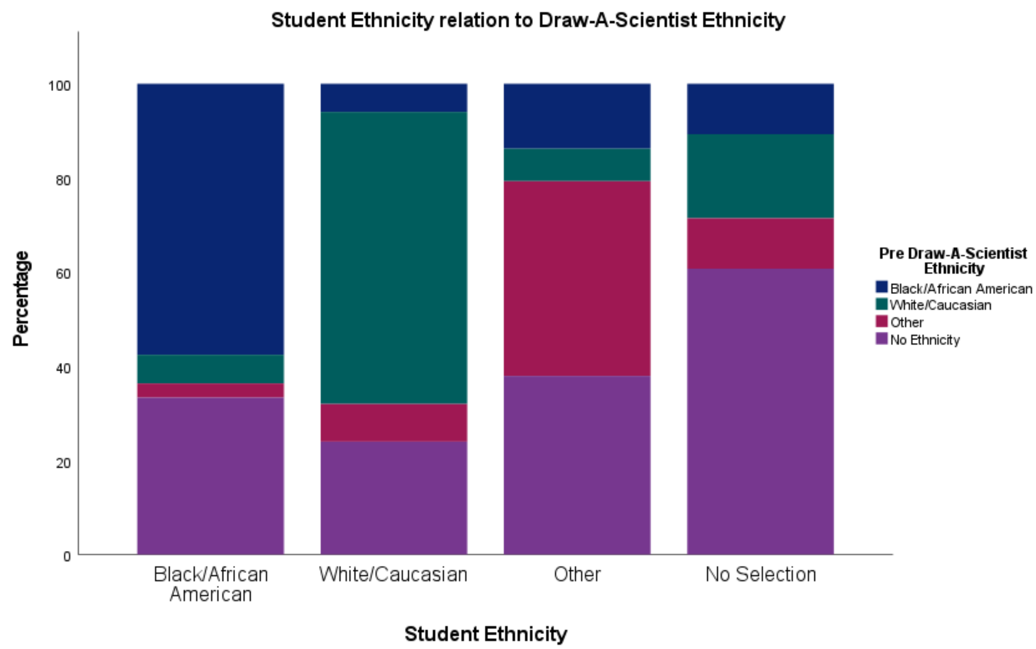

Figure 4.1. Stacked bar graphs indicating relationships between student ethnicity and initial Draw-A-Scientist ethnicity.

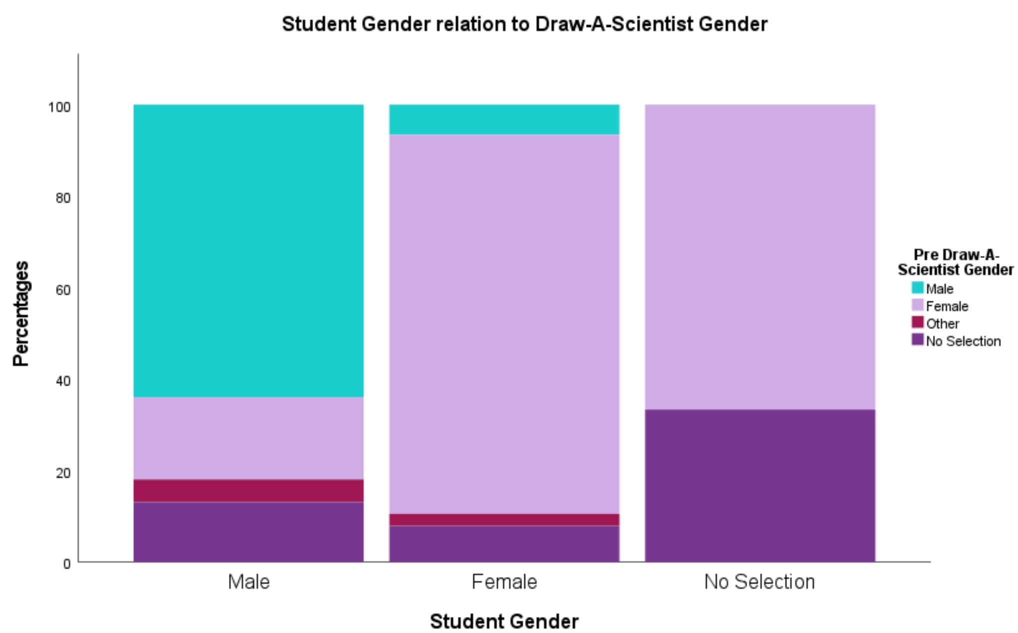

Figure 4.2. Stacked bar graphs indicating relationships between student gender and initial Draw-A-Scientist gender. “Other” was excluded from the x-axis as no students selected this option.

Treatment and DAS/Personal Meaning Map (PMM) Tests

To compare citizen science and non-citizen science interventions to changes in drawn scientists and PMMs for categorical variables, I used 3-way contingency tables. There was no relationship between treatment and the given variables for either the scientists or PMMs (Tables 4.3 & 4.4). Students did not significantly alter their scientists' ethnicity or gender with program treatment or pre-post changes. PMMs remained similar in concepts written by students and overall affect towards ocean health and climate change regardless of treatment or influence of the program.

All continuous variables failed Shapiro-Wilkes tests of normality. Therefore, I ran Mann Whitney U tests for all continuous dependent variables. There were no significant differences between treatments for any of the factors for either PMMs or scientists (Table 4.5).

Table 4.3. Results from 3-way contingency tables for DAS. Time is referred to as the Pre-Post time periods and treatment is referred to as Citizen Science and Non-Citizen Science treatments. Interaction effects are designated by x's under the interaction column.

Ethnicity			
Interaction	**G2**	**df**	**p-value**
Time x Treatment x Ethnicity	9.92	10	0.4475
Time x Ethnicity	2.52	3	0.4717
Treatment x Ethnicity	6.68	3	0.0828
Gender			
Interaction	**G2**	**df**	**p-value**
Time x Treatment x Gender	7.2	10	0.7064
Time x Gender	2.48	3	0.4789
Treatment x Gender	2.64	3	0.4505
Clothing			
Interaction	**G2**	**df**	**p-value**
Time x Treatment x Clothing	6.25	10	0.7947
Time x Clothing	2.82	3	0.4202
Treatment x Clothing	2.18	3	0.5359
Glasses			
Interaction	**G2**	**df**	**p-value**
Time x Treatment x Glasses	4.42	4	0.3521
Time x Glasses	0.2	1	0.6547
Treatment x Glasses	0.52	1	0.4708
Environment			
Interaction	**G2**	**df**	**p-value**
Time x Treatment x Environment	4.88	10	0.899
Time x Environment	0.24	3	0.9709
Treatment x Environment	1.98	3	0.5766

Table 4.4. Results from 3-way contingency tables for PMM. Time is referred to as the Pre-Post time periods and treatment is referred to as Citizen Science and Non-Citizen Science treatments. Interaction effects are designated by x's under the interaction column.

Ocean Literacy Principles (OLP)			
Interaction	**G2**	**df**	**p-value**
Time x Treatment x OLP	6.52	7	0.4805
Time x OLP	2.98	2	0.2254
Treatment x OLP	3.08	2	0.2144
Climate Change Affect (CCA)			
Interaction	**G2**	**df**	**p-value**
Time x Treatment x CCA	7.62	7	0.3673
Time x CCA	5.34	2	0.0693
Treatment x CCA	0.86	2	0.6505
You Affect (YA)			
Interaction	**G2**	**df**	**p-value**
Time x Treatment x YA	1.16	4	0.8846
Time x YA	0.72	1	0.3961
Treatment x YA	0.16	1	0.6892
Ocean Health Affect (OHA)			
Interaction	**G2**	**df**	**p-value**
Time x Treatment x OHA	5.98	7	0.5421
Time x OHA	0.06	2	0.9704
Treatment x OHA	3.92	2	0.1409

Table 4.5. Mann Whitney U-Tests for continuous dependent variables. Age was filtered for only scientists where age was given. Worksheets that did not have any words or phrases on the PMM were filtered out of the dataset. Delta variables were calculated by subtracting pre values from post-values. Independent variables were Citizen Science and Non-Citizen Science Treatments.

Draw-A-Scientist				
Dependent Variable	**n**	**U**	**Standard Error**	**p-value**
Age	92	998.5	123.933	.994
Number of Regular Objects	145	2664.5	93.864	.674
Number of Research Objects	145	2465.5	171.462	.352
Personal Meaning Maps				
Dependent Variable	**n**	**U**	**Standard Error**	**p-value**
Number of Total Words	113	1653.0	168.473	.669
Number of Words Around Climate Change Box	113	1457.0	137.472	.367
Number of Words Around Ocean Health Box	113	1473.0	142.605	.449
Number of Words Related to Ocean Literacy Principles	113	1609.0	107.681	.795

Discussion

Hypotheses

The research in this chapter aimed to understand the impacts of informal education through virtual reality and citizen science. I assessed this through the following research questions: 1) How does student identity influence marine science identity? 2) How does citizen science influence student science identity and scientist perceptions? 3) How does citizen science influence student conceptual understanding and attitudes towards climate change and ocean health?

My analyses revealed that 1) Students tend to identify most closely with marine scientists of the same gender and ethnicity as themselves, 2) The use of citizen science did not significantly alter student perceptions of marine scientists, 3) The use of citizen science did not significantly alter student attitudes towards or conceptual understanding of climate change and ocean health.

Marine Science Identity

Although my research question related to changes caused by citizen science did not reveal any novel changes, my exploratory question on the relationship between student identity and science identity did. The Draw-A-Scientist test assessments revealed that marine scientists' student drawings tended to echo students' own genders and ethnicities. In Chambers' first iteration of this test in 1983, students of all genders and ethnicities were likely to draw one depiction of a scientist: an older, white male with crazy white hair, a lab coat, and surrounded by beakers and test tubes. Stereotypical images such as this have been pushed by the media, causing young students to believe in this one depiction of a scientist (Steinke, 2017; Thomson et al., 2019). Other studies have found that through the decades, this depiction of a scientist has changed to showcase more women, ethnicities, and ages (Miller et al., 2018). However, current studies suggest that these stereotypes persist in modern elementary classrooms (Thomson et al., 2019). In the case of my research, I found that students tended to draw marine scientists of the same ethnicity and gender as themselves. While students drawing figures that represent themselves is not novel (Hawkins, 2002), no study to my knowledge has shown the connection between student gender and ethnicity to their views of marine scientists.

The implications of this connection can be important for the future of ocean health and climate change. As stated earlier, students often feel helpless about combating issues related to climate change and declining ocean health due to misunderstandings of underlying causes (Ojala, 2015; Stevenson and Peterson, 2016; Clayton et al., 2017). While the Personal Meaning Map assessment revealed that students did not gain much of an increase in conceptual understanding, their initial connection to marine scientist identity suggests that these elementary students may firmly believe that individuals of their ethnicity and gender can become marine scientists. Many of the students talked about scientists being of any race or gender in their drawings (Figure C-3). In some ways, this is even more encouraging. When students dissociate from their science identity, other issues can occur, such as a lack of motivation and attrition from STEM (Trujillo and Tanner, 2014; Starr, 2018). However, when students can identify as scientists and feel that they belong in science, they are more likely to persist through higher education and pursue a STEM career (Merolla and Serpe, 2013; Trujillo and Tanner, 2014). Additionally, by building on existing identity recognition, science identity can continue to be fostered for prolonged periods (Trujillo and Tanner, 2014). Because students were able to identify as marine scientists from the onset of the project, this suggests that marine science may be a potential avenue for building motivation and identity in young scientists.

Citizen Science as a Learning and Identity Tool

While my research did not reveal any increases in science identity or conceptual understanding and emotional affect towards climate change/ocean health, this does not mean that citizen science is not an important learning tool. Various other studies have shown the role that citizen science can play as a tool to increase motivation, engagement, and cognition among young students (Jenkins, 2011; Rotman et al., 2013; Dean et al., 2018; Kermish-Allen et al., 2019). These are all underlying concepts that enhance overall understanding and influence changes in student attitudes and identity (Mayer, 1998; Keller, 2008; Chinn et al., 2014). I believe that further exploration of citizen science should be employed in marine science contexts over more extended periods to unearth these potential impacts, particularly regarding ocean health and climate change.

Using VR for Citizen Science

The other important element of this program was the use of VR. I did not focus specifically on student gains found from using VR, as the benefits on student engagement, motivation, and understanding are widely understood (Bailenson et al., 2008; Allcoat and von Mühlenen, 2018; Duwan et al., 2019). However, the results shown in my study suggests that VR can be used effectively for connecting science and outreach. Specifically, scientists can use 360 videos and VR to show the public (especially young scientists) a more in-depth look into their research than explanations alone can provide. For scientists interested in employing the public to assist with data collection, VR can provide a means of exploring areas that may be unreachable to the average person (Mazumdar et al., 2018). In my study, elementary students could explore a coral reef environment that would be inaccessible to them due to specific skill requirements like SCUBA diving. Despite the lack of gains found from this program, students throughout the study remained engaged and excited, asking to continue their exploration of the reef even after the program was completed. This excitement can also be seen through PMM tests (Figure C-4).

Limitations and Future Directions

From my findings, it is evident that there were many limitations to this research. While I believe that both the DAS and PMM tests were adequate assessment tools for evaluating identity, conceptual understanding, and emotional affects, my implementation and evaluation of these tools leave room for improvement. Because of time limitations, assessments were completed within an hour of each other. Additionally, previous studies assessing changes in conceptual understanding after using VR have shown that testing immediately after the intervention is the most accurate representation of cognitive growth

(Merchant et al., 2014). However, the time between pre-and post-tests may be too short. Other studies that utilize pre and post-tests in conceptual understanding or attitudes tend to do so after longer durations (generally weeks to months) (Stevenson et al., 2018; Markowitz et al., 2018). Because the time between tests can significantly alter changes seen between testing durations, careful considerations must be made for the period between assessments (Cuijpers et al., 2017). I believe this to be the case in my study, as many students drew similar scientists and completed similar PMMs before and after the assessment (Figures C-5-8). Students were also limited to ten minutes for each assessment, with some indicating that they needed more time to fill out their assessments (Figure C-9) fully. In future studies, longer time spans between pre and post tests should be used to assess program effectiveness.

Additionally, previous PMM and DAS assessments have often been paired with student interviews to understand deeper meanings behind drawings and words/phrases (Farland-Smith, 2012; van Winkle and Falk, 2015). Because of time constraints in schools, I was unable to conduct these interviews; therefore, it is likely that there were misinterpretations of particular drawings and PMMs. Interviews with students may have been especially critical to understanding pre-post changes as students initially identified closely with their scientists – leaving little room for quantitative growth from the program on student science identity.

More attention may need to be given to post VR teachings for the program itself. Previous studies on incorporating complex, open-ended lessons suggest that when paired with direct information (such as those provided from lecture-style instructions), conceptual understanding of a topic and transferability of skills learned are likely to significantly increase (Schwartz and Martin, 2004; Van Merriënboer et al., 2006). Additionally, exposure to a topic after increasing initial student motivation (as is often the case in informal learning settings) can lead students to engage more closely with the material over long periods (Mayer, 1998; Keller, 2008). As mentioned, I faced extreme limitations of time in this program. However, future iterations should include longer citizen science sessions with students and more attention to post-VR lessons.

Future directions for this project's data analysis will focus on the qualitative aspects of the data. Although there were no significant statistical changes from the program or citizen treatment shown in the quantitative analysis, I believe through observations of the worksheets that there were still some important implications for this work. Specifically, some worksheets have shown changes pre-post in going from statements like "I don't know" to explaining aspects of climate change, ocean health, or their impacts (Figures C-10-11). Additionally, some students drew scientists with happy expressions or wrote more emotional stories about their scientists after participating in the program, two variables that were not assessed (Figure C-12). While my measurements may not have indicated changes from the majority, I believe that many students benefitted conceptually and emotionally from this program.

Conclusions

My initial research questions sought to understand the role that citizen science can play in impacting science identity, conceptual understandings, and overall affect in the context of marine science. I cannot make any definitive conclusions on this impact on elementary students from the results seen in Chapter 4. However, my findings on the connection between students and marine science identity suggest that marine science may be one of the few areas where students of all genders and ethnicities believe that they can aspire to become scientists. This connection to identity is important, inferring that marine science may be an avenue for increasing the relationship between students and science. Although my citizen science intervention did not yield the results I expected, by fostering student connections with science and the ocean, I believe that future programs can continue to enhance awareness of climate change and ocean health while encouraging growth in young scientists.

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CHAPTER FIVE
CONCLUSIONS

Restatement of Project Goals

Climate change and its subsequent impacts on the ocean are cause for great concern for us and future generations (Padhy et al., 2015; Harborne et al., 2017; Pinnegar et al., 2019; Duarte et al., 2020). Despite these concerns, science curriculums in many states fail to acknowledge the underlying causes of climate change or that climate change exists (Colston and Ivey, 2015). Because of this, students at a young age can be oblivious to the facts and their role in mitigating climate change (Lambert et al., 2012). For students of any age, misunderstandings of climate change can cause extreme anxiety and despair if interventions are not prioritized (Ojala, 2015; Stevenson and Peterson, 2016; Clayton et al., 2017). These interventions must be carefully constructed in some states to subvert political polarization caused by climate change and focus on its "downstream" effects. In the case of many states, such as South Carolina, the ocean and coastline are arguably the most essential economic assets impacted by climate change (Daniels, 1992). By focusing learning experiences on the impacts of climate change on a non-politicized target such as the ocean, there is a potential to help students learn about climate change and change their understanding of it (Tallapragada et al., 2021). Furthermore, by integrating hands-on learning in science, additional positive effects for students, such as career development and self-efficacy, are also likely to be seen (Junge et al., 2010; Linn et al., 2015; Nelson et al., 2017).

My thesis work sought to understand the impacts of using experiential learning on elementary and undergraduate students to help them better understand climate change and ocean literacy. Additionally, I identified how different forms of experiential learning also assisted students in altering their behaviors and ambitions to mitigate issues caused by climate change. Specifically, the main objectives of this project were threefold. (1) Understand the impact of experiential research and outreach education on Creative Inquiry undergraduate alumni. (2) Assess the benefit of implementing project-based learning in an undergraduate outreach course. (3) Understand the impact of integrating experiential citizen science with elementary students.

Key Findings

Through this research, I have found implications that experiential learning can effectively integrate marine science and climate change concepts while enhancing student career development, science identity, and self-efficacy.

In Chapter 2, I identified the role of outreach and research on undergraduate student alumni who elected to take an experiential course focused on marine science. Specifically, I looked to understand which factors (duration of enrollment, mentorship experience, and course type) affected student gains (knowledge, careers, and attitudes) from experiential learning. For student groups involved in either outreach or research, I found that mentoring affected perceived knowledge of marine science concepts and marine science communication skills. Similarly, the duration of enrollment and mentoring impacted undergraduate career choices and factors that influenced those choices. Duration also influenced science identity and climate change threat perceptions. Students who were enrolled for longer durations indicated stronger science identities and felt strongly that climate change was a threat to aspects of ocean health. Finally, experiential course type influenced undergraduate perceptions of threats to ocean health.

Throughout Chapter 3, I investigated a different form of experiential learning – Project-Based Learning (PBL). With this study, I looked at how using PBL in an online setting could increase undergraduate student knowledge of ocean literacy, attitudes towards conservation, their belonging in science, and essential science-centered skills. From this study, it was difficult to attribute gains specifically to PBL due to issues with project design (specifically a lack of a control group). However, I did find that after taking a PBL-centered course, students experienced an increase in their conceptual understanding and skill development. I did not see any changes in student attitudes towards marine science or their belonging in science after participating in PBL.

In Chapter 4, I switched gears to focus on elementary school students. In this study, I used a comparative analysis to determine the effects of citizen science on elementary student science identity as well as attitudes and understanding towards climate change and ocean health. First, I wanted to understand how student identity influenced their drawing of a scientist. I found that students drew scientists of the same gender and ethnicity as themselves. Then, I looked at how participating in citizen science would alter student perceptions of a scientist. Finally, I assessed how citizen science influenced student understanding and attitudes toward climate change and its impacts on ocean health. Through these assessments, I did not find that citizen science led to any changes in knowledge or attitudes.

Implications

The concept of experiential learning and its benefits are not new or misunderstood (Dewey, 1938; Kolb, 1984). Nevertheless, new iterations of experiential learning should still be tested for their practicality and usefulness in different contexts. In the case of marine science, experiential learning has been used to integrate the public with ocean conservation for many years (Cigliano et al., 2015; McMillan et al., 2017; Dean et al., 2018; Tallapragada et al., 2021). However, these interactions have generally been limited to public outreach, with small integrations into undergraduate and elementary student learning.

This thesis shows a variety of ways that integrating experiential learning can assist students in learning about climate change and ocean literacy while fostering their connections with science and conservation. Through my work, I have shown that research, outreach, and project-based learning (when implemented correctly), are potential avenues for incorporating politically divisive topics such as climate change into a biology-based education, such as marine science for undergraduate students. Additionally, citizen science can be used as an engaging format for showing elementary school students the marine environment and the effects of climate change on it. All three of these chapters give new applications to experiential learning theory and show that educators can reach students through motivating and captivating methods that promote enjoyment and growth.

This thesis shows that research and outreach can go hand in hand. Undergraduate research students can learn by teaching others, and researchers can use elementary school outreach to assist in data collection while informing the public about their research. Through this work, I hope that climate change researchers and educators can understand the benefits of working with undergraduate and elementary students through outreach or research contexts. These provide substantial benefits for students while framing messages of climate change in fun, low-threat ways.

Future Directions

While many exciting discoveries have been made through this thesis, the work is not yet complete. In the upcoming months, I hope to integrate qualitative analyses into my findings for Chapters 3 and 4.

In Chapter 3, I posed that there were gains seen from the study. However, it is difficult to attribute these to the use of PBL specifically. Throughout both semesters of data collection, students participated in focus groups where they spoke about what they liked about the components of the semester. They also talked about what they learned and how they could apply that to their own lives and understanding. However, I have not yet been able to code these responses to find common themes that could be integrated into this chapter. In the future, I would like to include these to determine whether gains can be attributed to PBL or if compounded learning due to being exposed to this information throughout a semester-long course is the underlying cause.

In Chapter 4, I did not see any changes from my quantitative analysis due to the citizen science intervention. However, previous studies have indicated that citizen science has vast implications for identity development, knowledge gains, and attitude shifts. I would like to take a new approach to both the Draw-A-Scientist test and Personal Meaning Maps for this chapter. I plan to perform qualitative assessments of student drawings and the descriptions of their scientists. Then, I will look at any major themes from both the pre and post assessments to see if the overall affect and perceptions of these scientists have changed. Additionally, I would like to investigate more of a mixed-methods approach for the Personal Meaning Maps. Through this approach, I would like to qualitatively assess specific themes related to climate change and ocean health and then quantitatively calculate changes in occurrences of these themes between pre and post-maps. I believe that these collection methodologies may be better suited for this study rather than purely quantitative analyses, especially considering their exploratory nature.

My future plans are to pursue a Ph.D. with the Engineering and Science Education department at Clemson, starting this fall. I hope to continue investigating undergraduate experiential learning through research and outreach in my future research. Specifically, I hope to look more closely into many of the findings from chapter one on the support needed to provide undergraduates with a valuable learning experience. I have loved my time working on these projects but feel that my investigations into developing a foundation for undergraduate experiential learning are far from complete. In the future, I hope to develop a model that mentors of undergraduates in research and outreach can use to support their students and create the most impactful experience possible, much like mine did for me.

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APPENDICES

APPENDIX A
MULTIPLE MODEL COMPARISON (CHAPTER 2)

Table A-1. Multiple model comparison of seven multiple regression and one logistical regression models exploring eight dependent variables derived from student surveys. The independent variables included in the model were three fixed demographic covariates (age, sex, ideology) and four independent variables associated with aspects of the creative inquiry program (duration, mentorship, research emphasis, and outreach emphasis). A minimum ΔAICc approach was used to identify the best fit, equally probable models as indicated by gray shading for those with ΔAICc < 2.0. Individual factors significance are indicated in *italics* (P < 0.10), **bold** (P < 0.05) and **<u>bold underlined</u>** (P < 0.01).

	Age	Sex	Ideology	Duration	Mentor	Research	Outreach					
Dependent variable	β1	β2	β3	β4	β5	β6	β7	F	P	adj R^2	AICc	ΔAICc
Perceived Knowledge of Marine Science	0.0066	0.1293	0.0395	*0.1014*	**0.5824**			2.8304	0.0369	0.2337	74.954	0.000
	-0.0148	-0.0429	0.0473		**0.7002**			2.2155	0.0951	0.1394	76.398	1.444
	-0.0110	0.0173	-0.0457	**0.1250**				2.0315	0.1194	0.1209	77.059	2.105
	-0.0372	0.0427	0.0297		**0.6536**	-0.0893	-0.5693	2.0896	0.0923	0.1789	79.507	4.553
	-0.0433	-0.2347	-0.0580					0.6477	0.5912	-0.0365	80.236	5.282
	-0.0218	0.1531	0.0344	0.0772	**0.5919**	0.0886	-0.2490	2.0085	0.0979	0.1904	81.773	6.819
	-0.0617	-0.1317	-0.0703			-0.1506	-0.6539	1.1126	0.3790	0.0184	82.631	7.677
	-0.0376	0.0414	-0.0510	0.1054		0.1003	-0.2055	1.3496	0.2746	0.0653	83.523	8.569
Perception of Climate Change Threat on the Marine Environment	0.0270	0.1244	**<u>0.1226</u>**	**0.0515**		-0.2261	0.1809	4.0953	0.0057	0.3823	16.101	0.000
	-0.0109	0.1757	**<u>0.1185</u>**	*0.0349*				3.7887	0.0148	0.2710	16.673	0.572
	-0.0199	0.1054	**<u>0.1150</u>**					3.6885	0.0240	0.2118	17.162	1.061

	0.0152	0.0397	**0.1132**			**-0.3488**	-0.0382	3.4501	0.0166	0.2899	18.012	1.911
	-0.0158	0.1330	**0.1302**		0.1007			2.9645	0.0383	0.2075	19.262	3.161
	-0.0090	0.1879	**0.1277**	0.0323	0.0631			3.0216	0.0287	0.2520	19.626	3.525
	0.0285	0.1347	**0.1305**	*0.0489*	0.0548	-0.2272	0.1768	3.4507	0.0113	0.3637	19.725	3.624
	0.0187	0.0648	**0.1276**		0.0939	**-0.3399**	-0.0260	2.9889	0.0252	0.2845	20.656	4.555
Science Identity and Belonging	**-0.0451**	0.0071	0.0218	**0.0685**				4.5380	0.0065	0.3205	37.981	0.000
	-0.0420	0.0272	0.0372	**0.0642**	0.1046			3.6502	0.0129	0.3063	40.774	2.793
	-0.0629	-0.1310	0.0151					3.3457	0.0338	0.1899	41.498	3.517
	-0.0556	-0.0819	0.0421		0.1792			2.8440	0.0442	0.1974	43.143	5.162
	-0.0696	-0.8543	0.0093			-0.0938	-0.3174	2.6133	0.0493	0.2119	44.732	6.751
	-0.0548	0.0207	0.0209	*0.0646*		0.0599	-0.0425	2.8403	0.0311	0.2690	44.809	6.828
	-0.0638	-0.0441	0.0327		0.1545	-0.0793	-0.2974	2.3271	0.0651	0.2097	47.227	9.246
	-0.0520	0.0409	0.0368	0.0595	0.1069	0.0578	-0.0504	2.4439	0.0499	0.2520	48.230	10.249
Importance of Marine Science on Career	*-0.1258*	-0.1329	0.0463	**0.2164**				3.8630	0.0136	0.2762	112.135	0.000
	-0.1082	-0.0212	0.1314	**0.1929**	0.5809			3.4084	0.0175	0.2864	113.851	1.716
	-0.0181	-0.5694	-0.0251					2.7898	0.0596	0.1518	115.125	2.990
	-0.1489	-0.3489	0.1462		0.8050			2.8161	0.0472	0.1949	115.437	3.302
	-0.1473	-0.5223	0.0016			-0.8821	*-1.1310*	2.4421	0.0621	0.1937	117.635	5.500
	-0.1064	-0.2294	0.0342	0.1783		-0.4575	-0.3726	2.4675	0.0530	0.2269	118.745	6.610
	-0.1206	-0.3324	0.1105		0.7110	-0.8154	-1.0391	2.4388	0.0553	0.2234	118.883	6.748
	-0.0907	-0.1178	0.1196	0.1501	0.5909	-0.4692	-0.4160	2.3325	0.0592	0.2371	121.037	8.902
Marine Science Communication Skills	0.0189	-0.0075	0.0570	*0.0785*	**0.7357**			3.8940	0.0095	0.3253	67.982	0.000
	0.0023	-0.1409	0.0630		**0.8269**			3.7663	0.0152	0.2694	68.297	0.315

	-0.0438	-0.0174	0.0514		**0.7959**	0.2097	-0.4263	3.3223	0.0159	0.3171	70.768	2.786
	-0.0310	0.0741	0.0553	0.0641	**0.7447**	0.3575	-0.1603	3.0483	0.0202	0.3233	73.191	5.209
	-0.0032	-0.1490	-0.0507	**0.1083**				1.8424	0.1510	0.1009	74.730	6.748
	-0.0313	-0.0367	-0.0613					0.7743	0.5185	-0.0230	76.908	8.926
	-0.0736	-0.2300	-0.0704			0.1351	-0.5292	1.1755	0.3489	0.0284	79.290	11.308
	-0.0508	-0.0664	-0.0522	0.0996		0.3722	-0.1056	1.4016	0.2547	0.0743	80.199	12.217
Importance of the Program After Graduation	-0.0468	0.4967	0.1511		**0.6629**			3.1520	0.0307	0.2230	72.107	0.000
	-0.0382	0.5661	0.1479	0.4080	**0.6155**			2.6290	0.0482	0.2136	74.634	2.527
	-0.0738	0.3151	0.0513					1.6227	0.2073	0.0586	76.127	4.020
	-0.0568	0.4477	0.0577	0.0657				1.6438	0.1933	0.0790	77.377	5.270
	-0.0080	0.4257	0.1456		**0.6488**	-0.4207	-0.1044	2.2028	0.0781	0.1939	77.811	5.704
	0.0018	0.4975	0.1487	0.0497	**0.6090**	-0.3060	0.1020	1.9358	0.1097	0.1792	81.078	8.971
	-0.0323	0.2524	0.0463			-0.4815	-0.1883	1.1769	0.3483	0.0286	81.183	9.076
	-0.0143	0.3818	0.0600	0.0788		-0.2940	0.1467	1.2030	0.3386	0.0390	83.260	11.153
Pursuance of Further Education	*1.0985*	1.2829	0.1430	*-0.4276*				18.6570	0.0009		35.122	0.000
	1.3261	1.8268	0.6023	**-0.5447**	2.3397			20.8549	0.0009		36.026	0.904
	0.7826	1.8452	0.2492					14.3409	0.0025		36.578	1.456
	0.8194	2.0659	0.3814		0.7227			14.6906	0.0054		39.090	3.968
	0.7165	1.6758	0.2533			1.3532	1.8076	17.2945	0.0040		39.586	4.464
	1.0588	1.2972	0.1491	-0.3903		0.1056	0.2360	18.6780	0.0047		41.572	6.450
	0.8164	2.0091	0.4771		1.3080	1.4323	*2.0499*	18.1835	0.0058		42.067	6.945
	1.4208	1.7488	0.6196	-0.6050	2.4093	-0.4987	-0.3301	20.8970	0.0039		43.028	7.906

APPENDIX B
PROJECT BASED LEARNING (PBL) PROJECT COMPONENTS (CHAPTER 3)

Table B-1. Ocean literacy principles and ecological themes were assigned to students. Principles and themes were chosen in accordance with outreach objectives for my course. Assignments were randomized among student groups.

Marine Ecology Themes			
Anthropogenic	*Keystone*	*Foundational*	*Charismatic*
Human interactions and impacts with the marine environment (and vice-versa)	Species that keep a marine ecosystem from collapsing, critical organisms in that environment	Organisms the build the foundation for a marine ecosystem	Animals which humans have a special affinity for, generally used as "poster children" for the marine environment
Ocean Literacy Principles			
OLP 1	OLP 4	OLP 5	OLP 6
The earth has one big ocean with many features	The ocean makes the Earth habitable	The ocean supports a great diversity of life and ecosystems	The oceans and humans are inextricably interconnected

Table B-2. Rubric used for grading project-based learning components. Point values are excluded from this table.

Criteria	**Ratings**				
	Exceeds Expectations	**Meets Expectations**	**Approaches Expectations**	**Does Not Meet Expectations**	**No Submission**
Main Ocean Principle	Ocean principle is addressed throughout the entire module	Ocean principle is addressed throughout most of the module	Ocean principle is somewhat addressed in the module	Module does not address the given ocean principle	Module was not submitted
Theme	The module is centered around the given theme	Theme is present throughout most of the module	Theme is present through some of the module, but not much	Module does not address the given theme or the wrong theme is addressed	Module was not submitted
Overall Organization of the Module	Module has an excellent organization and contains a clear beginning, middle, and end	Module is organized well but contains some issues	Module has a lot of organization issues which hinders understanding of the concepts	Module is not organized and does not allow for proper understanding of the themes/concepts	Module was not submitted
Interactive Components	Module contains 5+ interactive components	Module contains 3-4 interactive components	Module contains 1-2 interactive components	Module does not contain any interactive components	Module was not submitted
3rd – 5th Grade State Standards	Module addresses 1-2 state standards in each subject and all are properly identified	Module addresses 1-2 state standards for two subjects and are identified	Module addresses 1-2 state standards for one subject and only some are identified	Module does not address any state standards/none are identified	Module was not submitted
Problem	Module is based around and open-ended problem with large-scale consequences and multiple solutions; is engaging and contains tools to address the problem	Module is based around an open-ended problem that has multiple solutions, but lacks engagement and problem-solving tools	Module is based around a problem, but problem is not open-ended	Module is not based around any problem (all lecture-style)	Module was not submitted

APPENDIX C
DRAW-A-SCIENTIST AND PERSONAL MEANING MAP A
SSESSMENT EXAMPLES (CHAPTER 4)

Draw what you think a marine scientist looks like….

Is your scientist a boy/girl/other? What race is your scientist? How old are they? What are some cool facts about them? Describe your drawing below:

____

____

____

Figure C-1. Blank Draw-A-Scientist prompt given to students as a pre- and post-assessment.

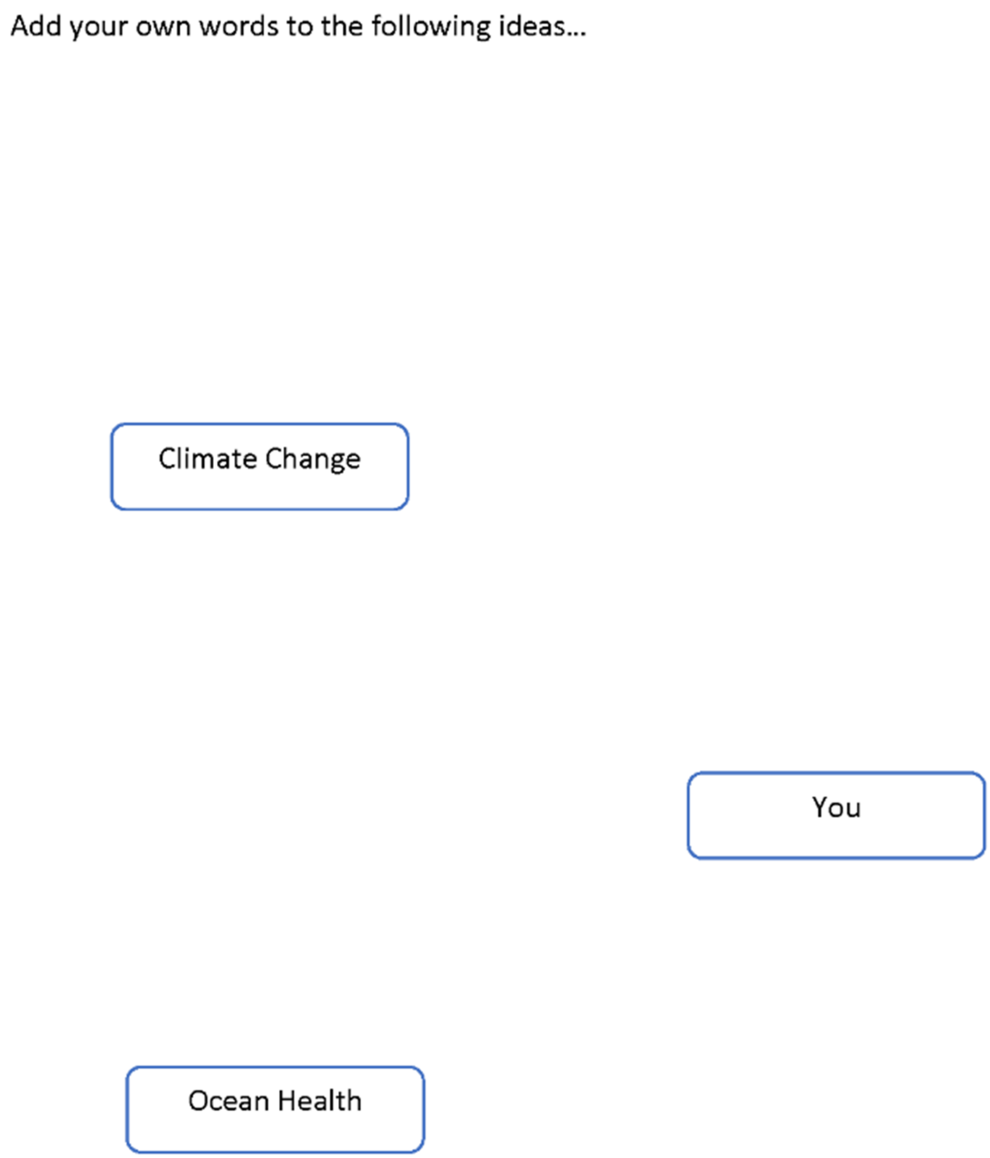

Figure C-2. Blank Personal Meaning Map prompt given to students as a pre- and post-assessment.

Draw what you think a marine scientist looks like….

Is your scientist a boy/girl/other? What race is your scientist? How old are they? What are some cool facts about them? Describe your drawing below:

They can be any Gender.ors

The are 18 years old or older.

They study the ocean.

Figure C-3. Pre-PMM assessment indicating that scientists can be any age or gender

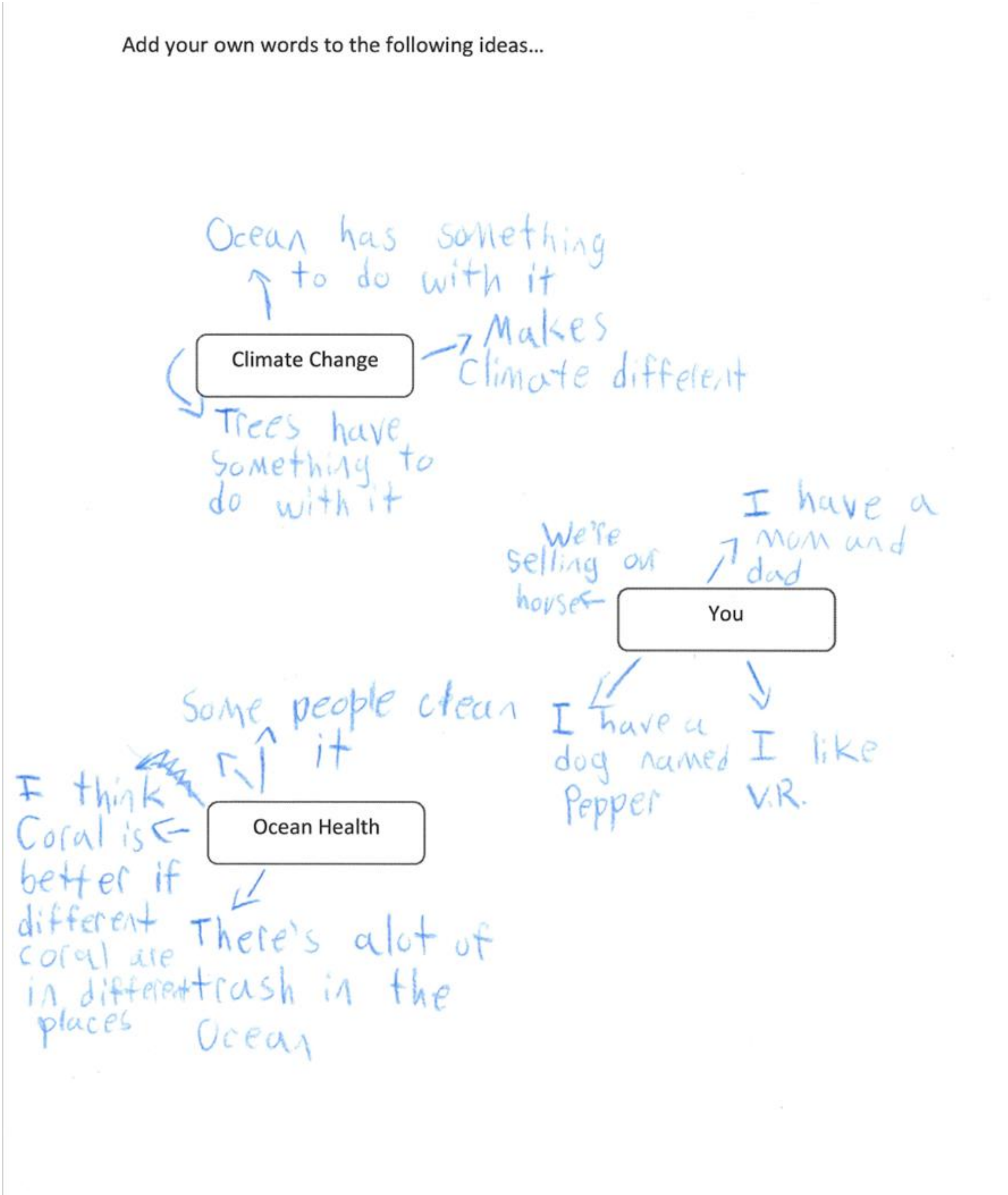

Figure C-4. Post PMM showing student interest in VR and information about climate change and ocean health

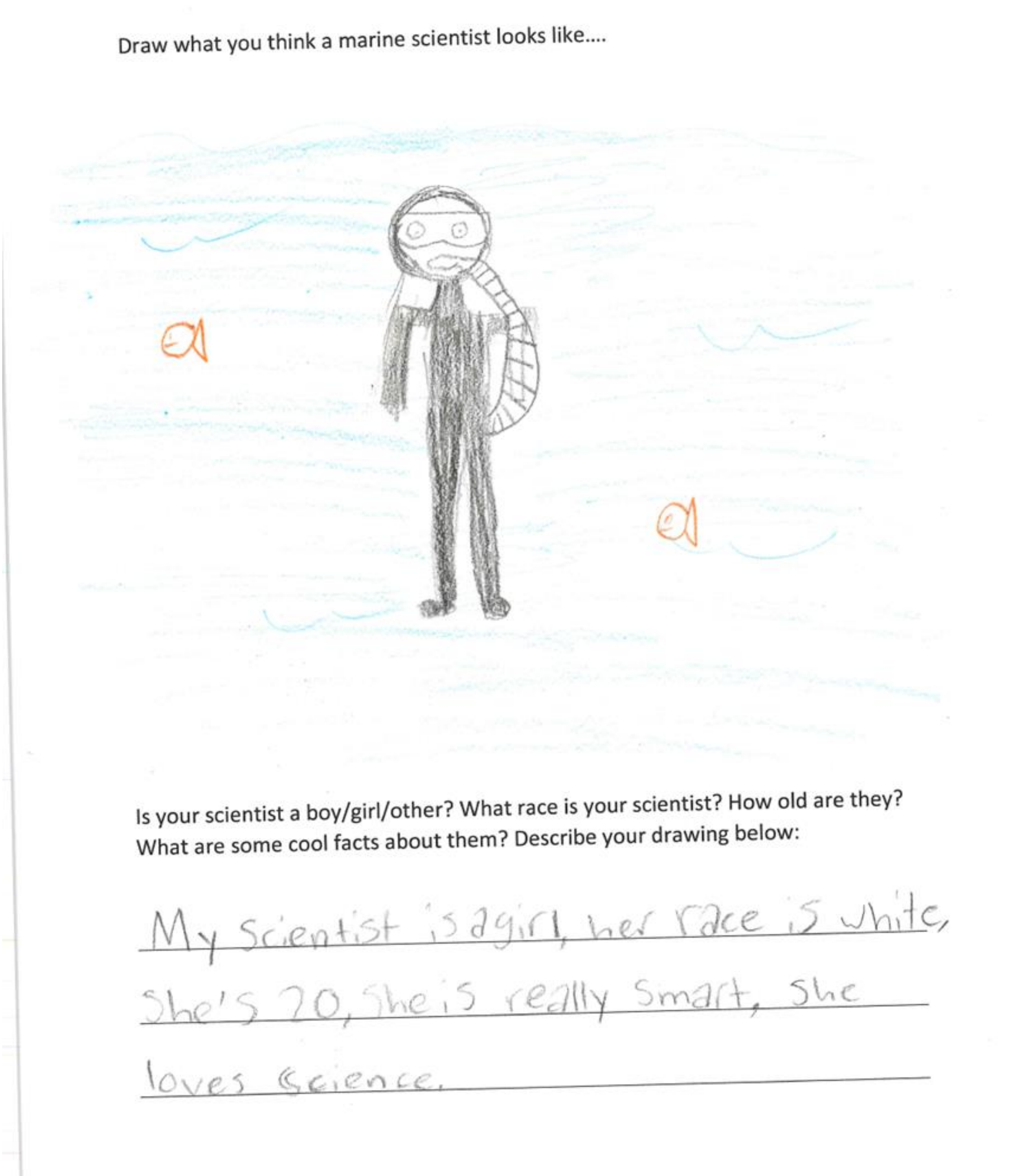

Figure C-5. Pre DAS assessment example with identical scientst drawn pre-post.

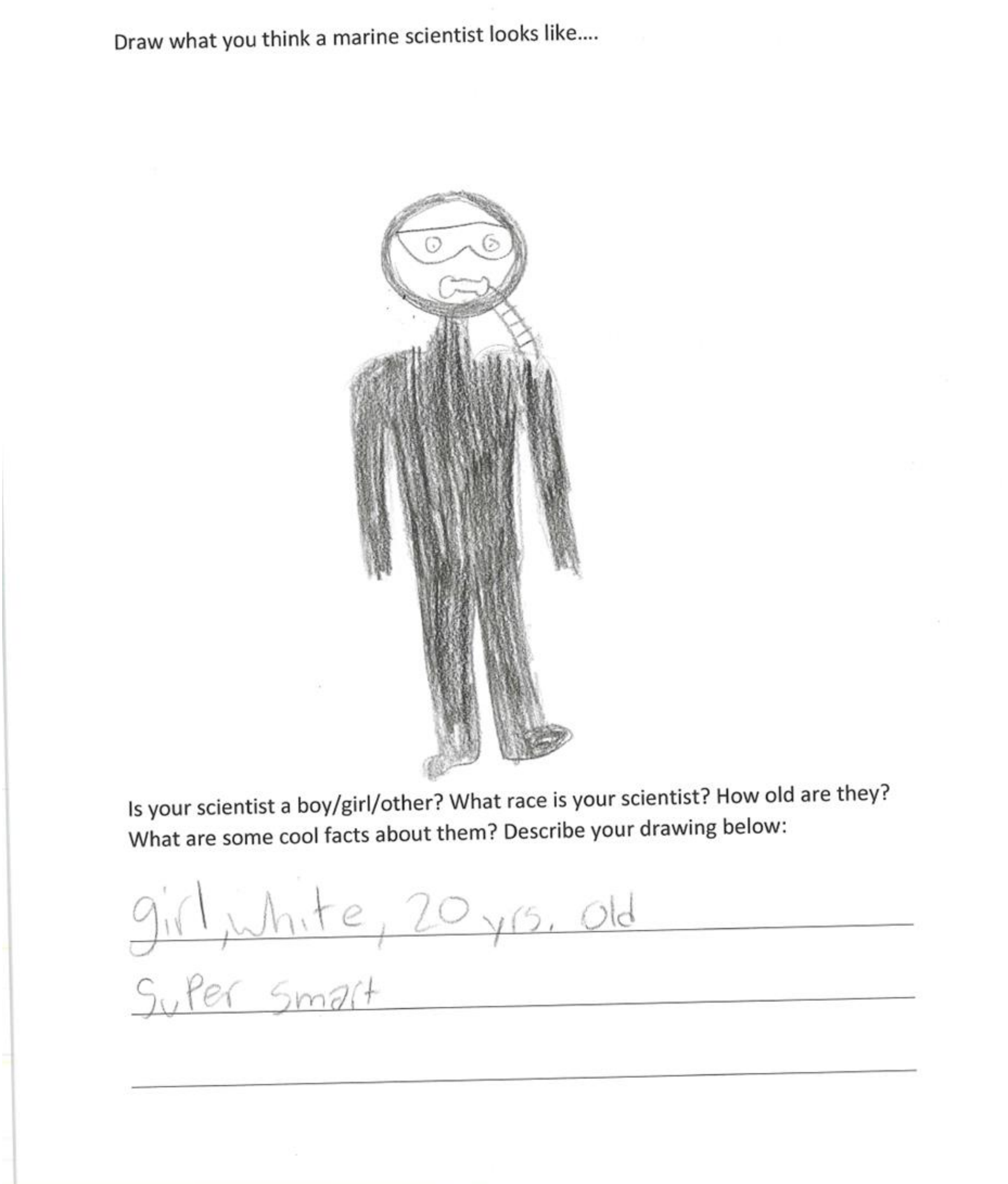

Figure C-6. Post DAS assessment example with identical scientst drawn pre-post.

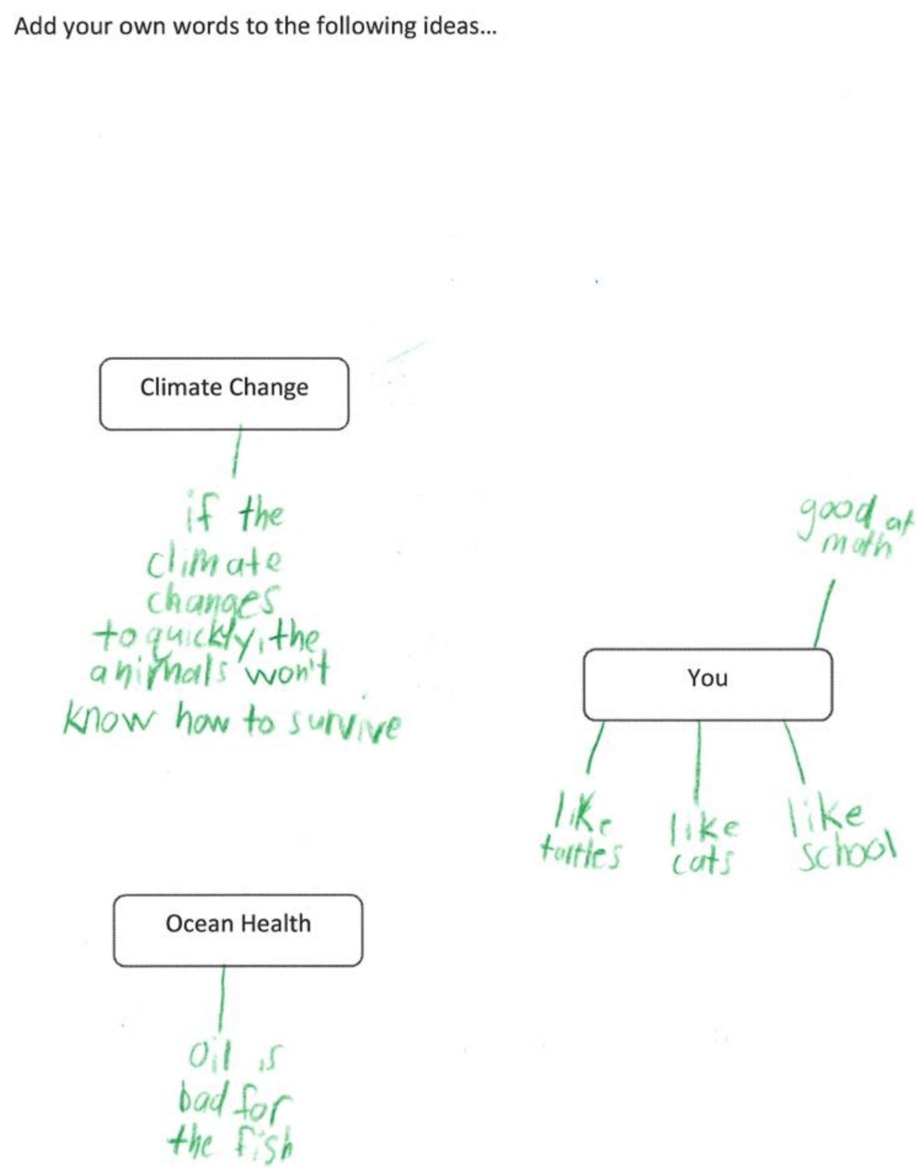

Figure C-7. Pre PMM assessment example with almost identical phrases written pre to post.

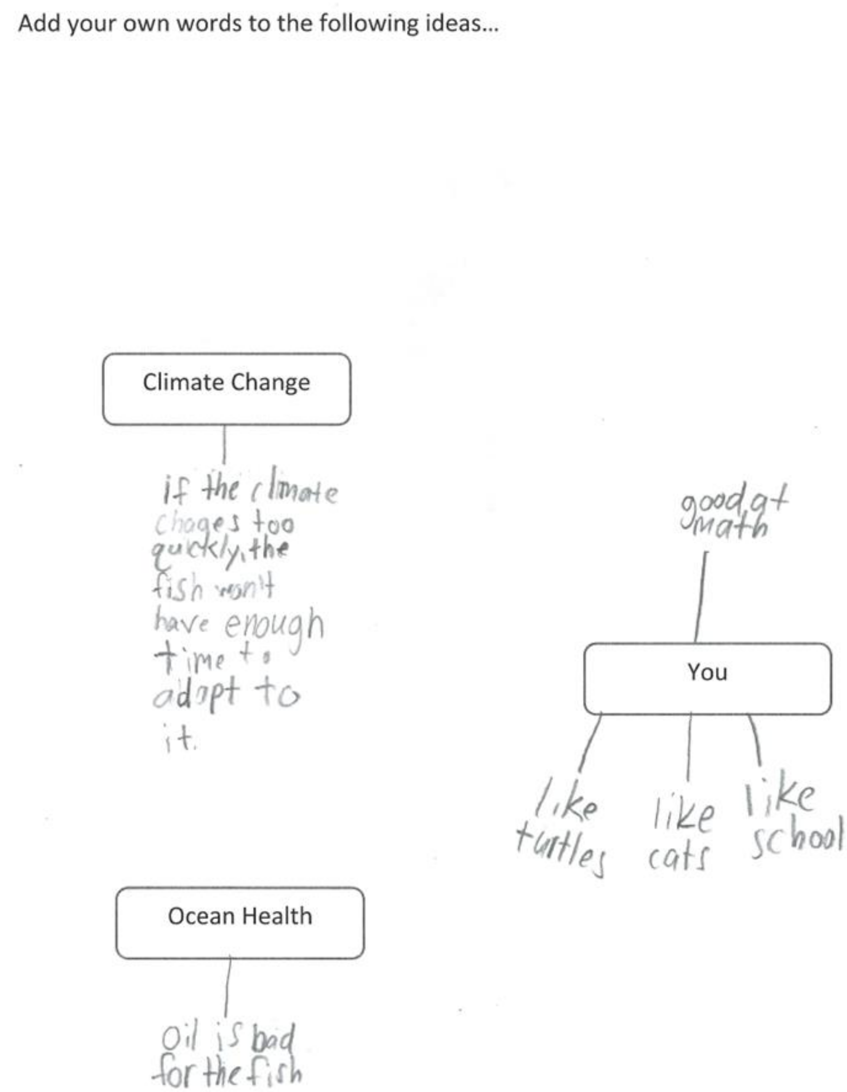

Figure C-8. Post PMM assessment example with almost identical phrases written pre to post.

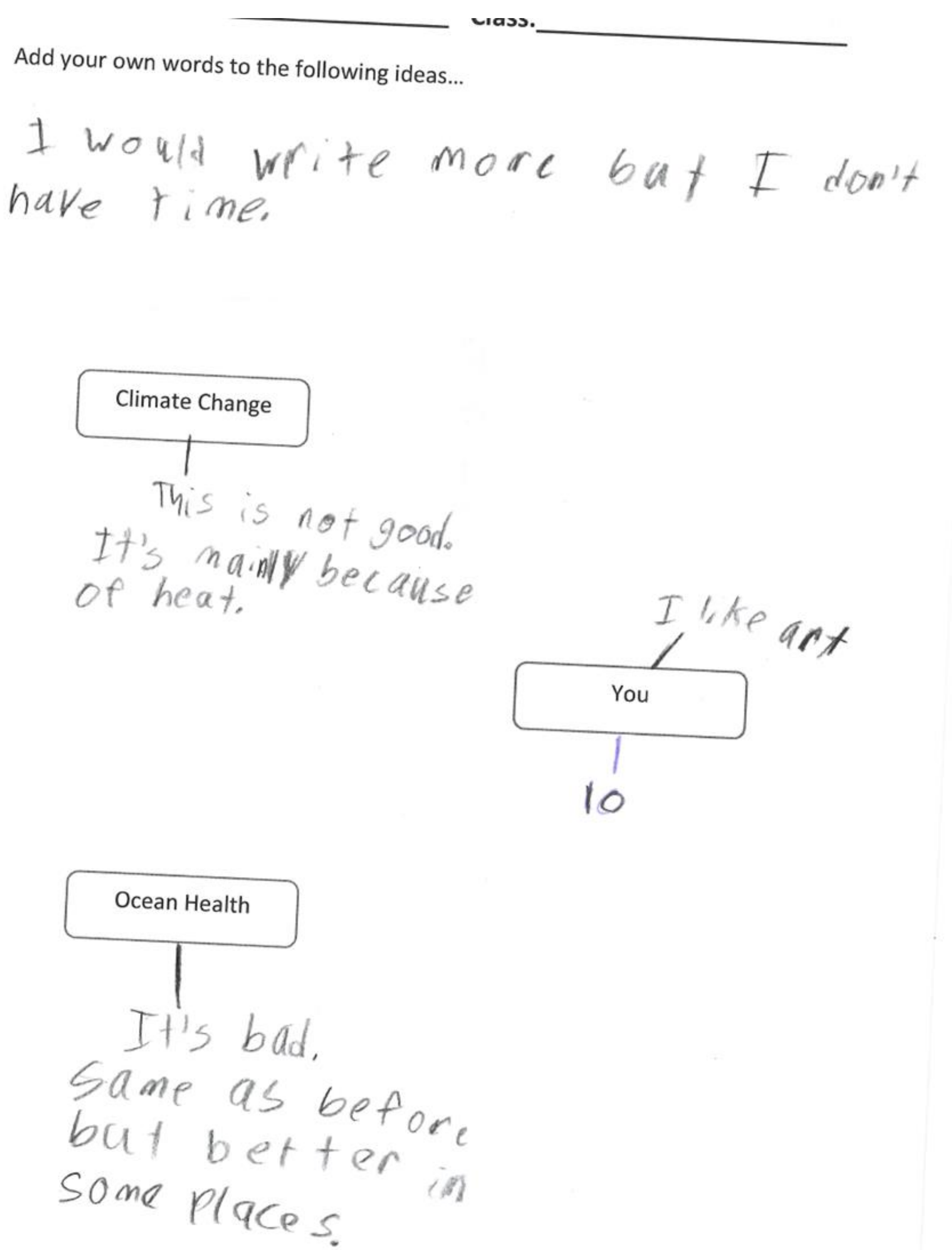

Figure C-9. Example of completed Personal Meaning Map with student indicating they did not have time to complete their assessment.

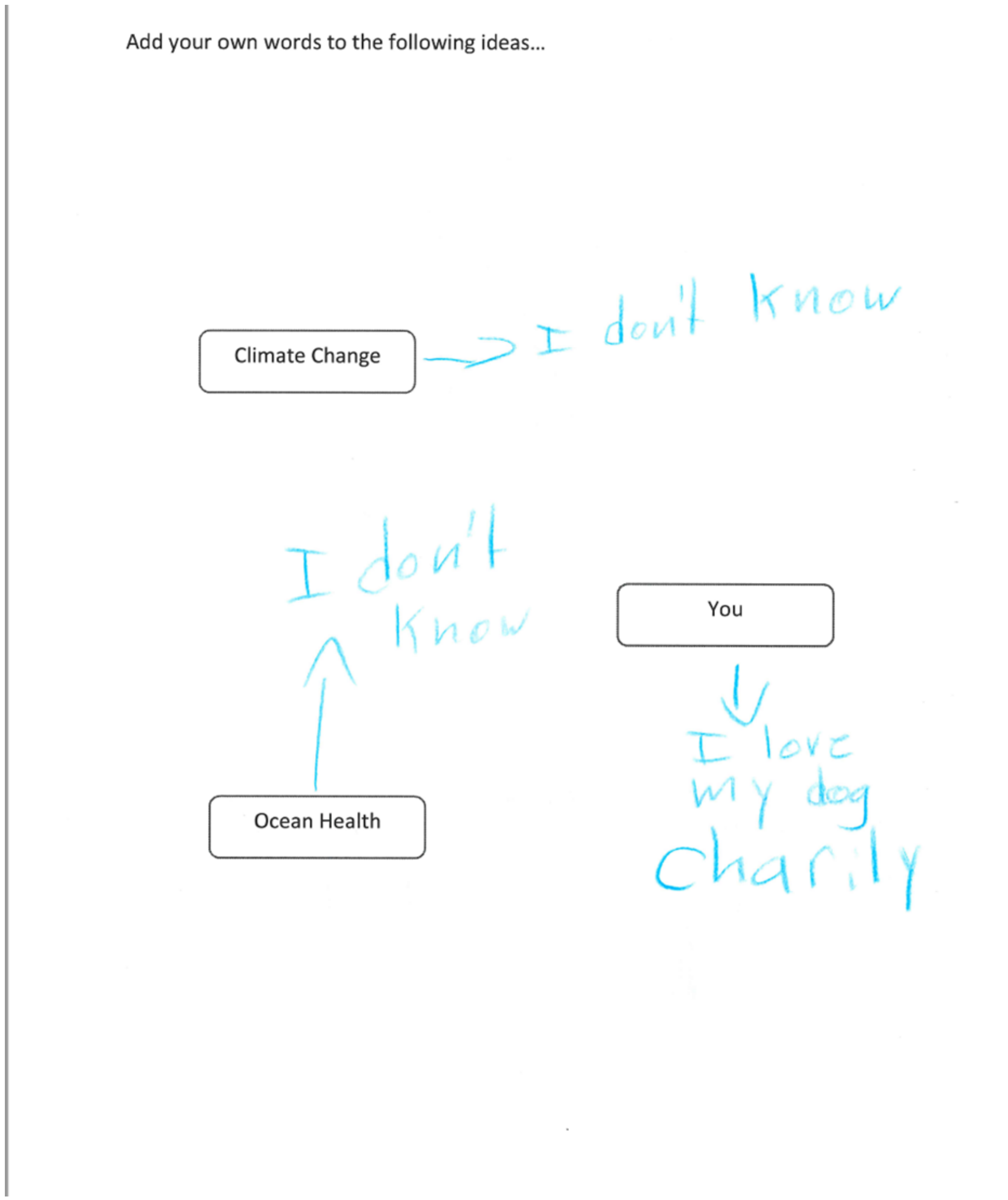

Figure C-10. Example pre-assessment showing students indicated "I don't know" for both Climate Change and Ocean Health. Student also wrote about their dog for their You box.

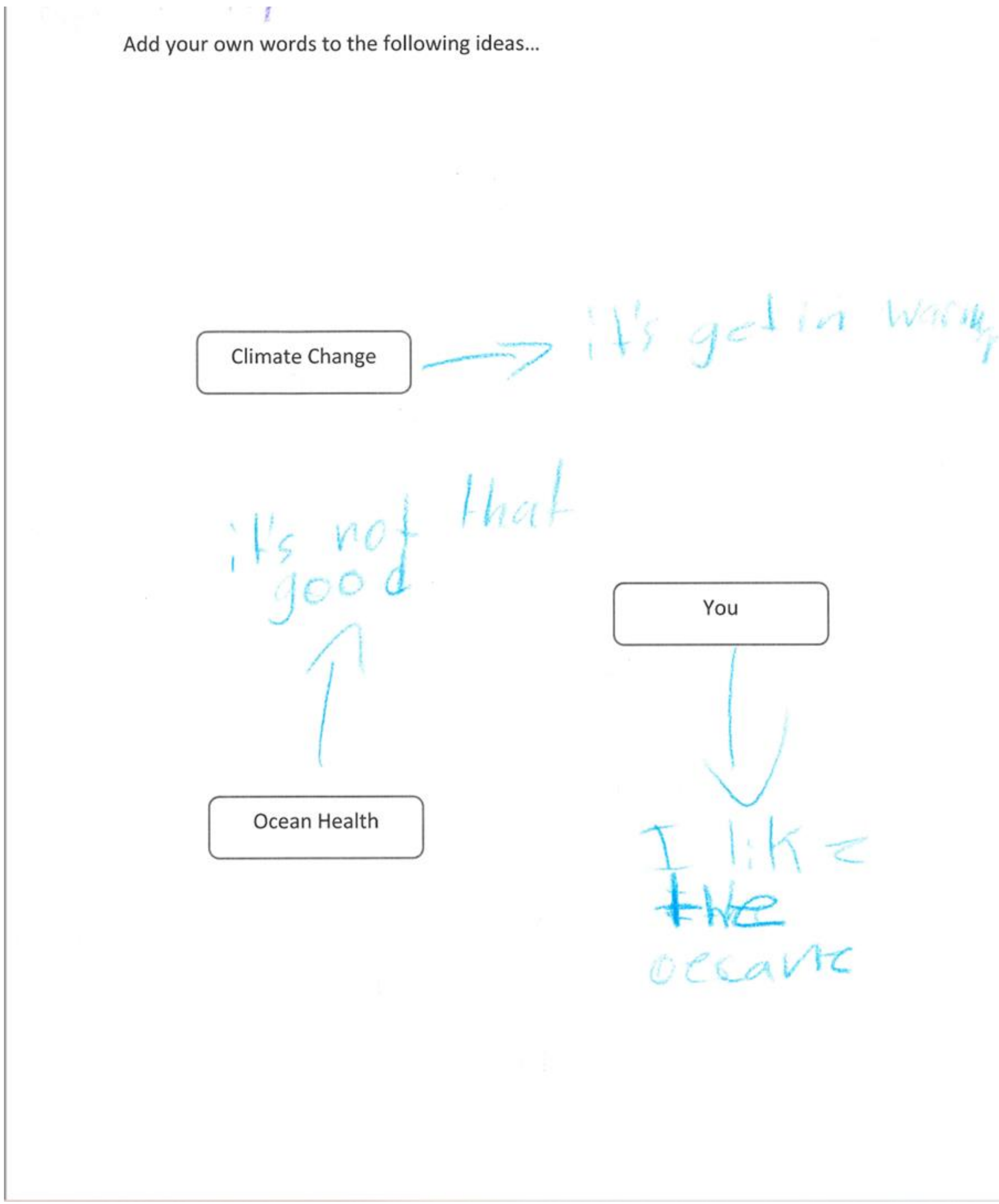

Figure C-11. Example post-assessment showing changes in understanding of climate change, ocean health, and their connection to the ocean. Student wrote “it’s getin warmer” for the Climate Change box, “it’s not that good” for the Ocean Health box, and “I like the ocean” for the You box.

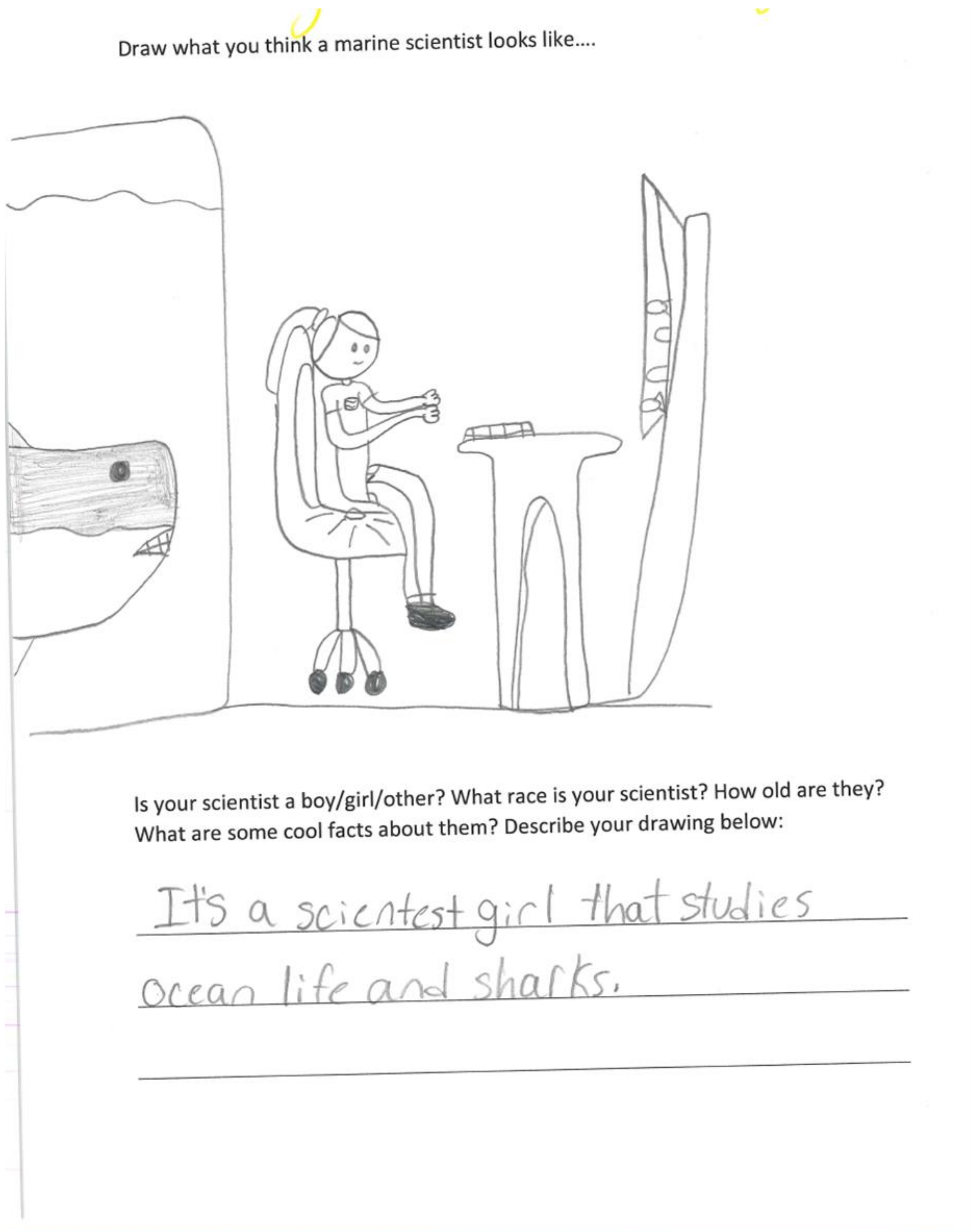

Figure C-12. Example of drawn scientist with a happy expression.

APPENDIX D

CITIZEN SCIENCE CODEBOOK (CHAPTER 4)

Directions: Please follow all directions as written in the codebook. Pages in the pre category will have "pre" written in the upper-righthand corner of the page. Pages in the post category will have "pro" written in the upper-righthand corner of the page. All data should be submitted in Qualtrics at this link: https://clemson.ca1.qualtrics.com/jfe/form/SV_6Pagg7FlePLyZb8

Worksheet Information

- *Select the correct school code:* Select the correct school identifier from the first quarter of the code on the file name
  - Example: S01-01-05-01
- *Select the correct teacher code:* Select the correct teacher identifier from the second quarter of the code on the file name
  - Example: S01-01-05-01
- *Select the correct grade code:* Select the correct grade identifier from the third quarter of the code on the file name
  - Example: S01-01-05-01
- *Select the correct student code:* Select the correct student identifier from the fourth quarter of the code on the file name
  - Example: S01-01-05-01

Demographic Information

- *What gender did the student identify as?:* Select the gender that the student chose. If the student filled in the blank, select "other" and type exactly what the student wrote. If the blank was filled in with an answer choice – only select that answer choice. If the student did not fill this out then select "none".
- *What race did the student identify as?:* Select all races that the students chose. If the student filled in the blank, select "other" and type exactly what the student wrote. If the student did not select a race, select "none".

Draw a Scientist

There will be a pre and post drawing (indicated on the upper-right hand side of the page). Answer the questions about your scientist(s) in the corresponding pre or post section.

- *How many scientists are in the drawing?:* Only count humans drawn. If the student wrote about a scientist (or scientists) count the number of scientists the student indicated. If the student did not draw or write about a scientist select "none".

You will fill in all of the following characteristics for each scientist. Start with the scientist on the left and work to the right. After you finish feeling out the information for a *scientist, another section will appear until all of the scientists are characterized (this is based on the number you entered above).*

- *Gender*: What gender is your scientist? This can be written below the drawing to help you decide. Otherwise indicate to the best of your ability. Select one answer.
- *Race:* What race is your scientist? This can written below the drawing to help you decide. Otherwise indicate to the best of your ability. Select all answers that might apply.
- Age: What age is your scientist? Only write the age if the student directly identified what age their scientist is. Otherwise choose "unidentifiable".
  - If a student put multiple ages, but only one scientist, take the average (use rounding rules if necessary to get to a whole number).
- *Clothing:* What type of clothing is your scientist wearing? Select all that apply.
  - *Laboratory* – Wearing a lab coat, face shield, or other typical lab gear
  - *Field Gear* – Wearing SCUBA equipment, waders, bathing suits, snorkeling gear, fishing hats or other typical field gear
  - *Casual* – Wearing casual clothes such as shorts, t-shirts, jackets, jeans, skirts, dresses, hats or other casual clothing
  - *Business* – Wearing business clothes such as polos, khakis, formal dresses, suits, tuxedos, or other business attire
  - *Other (typed answer)* – Other types of clothing not listed here
  - *None* – No identifiable articles of clothing
- Glasses: Is the scientist wearing glasses? These should only be typical reading glasses or everyday use glasses – not sunglasses or goggles.
- Environment: What does the background of the drawing look like? Include animals, plants, furniture, or other objects in your determination.
  - *Laboratory* – Background looks like a laboratory setting. May contain microscopes, desks and cabinets, fume hoods, pipettes, beakers, fish tanks, hot plates, computers, etc.
  - *Field* – Background looks it is in or near a marine habitat. Animals and plants are considered part of the background and may be used to inform if the scientist is in a field environment.
  - *Classroom* – Background looks like a typical classroom. May contain whiteboards, blackboards, computers, books, desks, or students.
  - *Other* – Background is something different than one of the ones listed. Type in a designation for what you think the background is.
  - *No Background* – There is nothing in the background of the scientist to determine where the image takes place.

- Objects: How many objects are in the drawing? Use the slider to indicate your count data. Only count man-made objects, not animals, plants or other humans. Do not count any objects that may help to identify the background (such as ocean animals, coral).
  - *Research* – Objects that pertain to the scientist's ability to collect scientific data or conduct experiments. Do not count articles of clothing such as lab coats or SCUBA gear. Examples include objects such as microscopes, data sheets, computers, cameras, beakers, pipettes, test tubes, boats, nets, etc.
  - *Other* – Objects that do not pertain to research. These may be simple objects such as headphones, skateboards, footballs, etc.
- Written Description: Write the description word for word written by the student. Include any misspellings and punctuations. Only transcribe what is written below the scientist (where it asks for the description). If anything is written on the drawing itself, put it in the notes.
- Additional Notes: Write any additional notes you have about the drawing here. If you have none, leave this blank.

Personal Meaning Maps

There will be a pre and post personal meaning map (indicated on the upper-right hand side of the page). Answer the questions about your map in the corresponding pre or post section.

- *How many words and phrases are connected to/surrounding each block?*
  - Count the number of words or phrases surrounding or connected to each individual box. If the student only wrote words (not as a phrase), count the words individually. If the student wrote phrases, count the number of phrases. If the student wrote a mix of words and phrases, use separations between the words or phrases (such as large spaces, periods, or semicolons) for your count.
- *Write the exact words/phrases surrounding each block.*
  - Write the exact words and phrases surrounding or connected to each box that you counted for the previous question. Separate phrases and words by semicolons.
- *How many words/phrases are written related to the following words?*
  - Count how many words/phrases written on the page are related to "ocean health" and "climate change". If a word/phrase seems to be related to both, count the one that is closest to the word/phrase. Do not count the phrase/word if the student indicates they don't' know (for example: idk).
- *What was the overall affect (emotion) connected to the following words?:*

    - What was the overall emotion of the words/phrases surrounding the words? See if the words or phrases are positive/negative/or neutral. For example, if a student said they were happy it was warm outside, you would not count this.
    - Overall affect: If you had two positive words, it would be positive. If you have a negative and positive word it would be neutral. If you had a positive and neutral word it would be positive. Relate this to the program only.
    - Examples of positive words/phrases are as follows: conservation, recycling, healthy ocean, a lot of fish, etc.
    - Examples of negative words/phrases are as follows: rising temperatures, dying fish, coral bleaching, trash, etc.
    - Any words/phrases that you did not count as positive or negative, count as neutral.
    - If you are not sure if a word or phrase is positive, mark it as neutral.
- *Which ocean literacy principles are referenced (select all that apply):*
    - Indicate all possible ocean literacy principles referenced.
    - Example: fishing would count as OLP#6: The ocean and humans are largely interconnected
- *Notes:* Any additional notes you have about the personal meaning map.