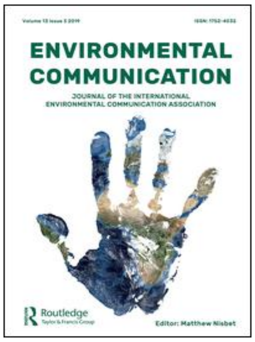

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Something Very Fishy: An Informal STEAM Project Making a Case for Ocean Conservation and Climate Change

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ABSTRACT
This paper reports about an informal learning experience – Something Very Fishy (SVF) – which is focused on ocean conservation and climate change. Results from 49 elementary school student workbooks indicated that experiencing SVF improved their understanding of ocean conservation, increased their interest in pursuing science careers, but did not affect their actions towards conservation. Survey results from 40 undergraduate students who helped run SVF indicated that the more efficacious they felt about communicating marine science and the more identified they felt with the scientific community, the more inclined they were to choose careers involving science communication. Survey results from 27 elementary school teachers, who accompanied their students to SVF, indicated perceived norms around teaching marine science and climate change affected their intentions to teach those topics in their classrooms. The paper concludes with implications of these findings on the future of SVF and programs alike, and research directions for environmental conservation in informal settings.

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Introduction

According to a recent United Nations report, our ocean is in danger (Bindoff et al., 2019). Sea levels are rising leading to severe floods (Borunda, 2019; Taherkhani et al., 2020) and the ocean is getting warmer resulting in brutal and frequent storms (Borunda, 2019; Yin et al., 2020). Our ocean is becoming more acidic and harmful for aquatic life due to the absorption of excess amounts of carbon emissions (Borunda, 2019; Doney et al., 2020). Severe plastic pollution is also threatening our ocean's ecosystems (Borunda, 2019; Litchfield et al., 2020). The ocean makes up the largest habitat on Earth and any negative disruptions in that habitat affects all other terrestrial habitats (Borunda, 2019; Doney et al., 2020; Hoegh-Guldberg & Bruno, 2010).

The National Science Education Standards published a report in 1996 (National Research Council [NRC], 1996) recognizing that the ocean sciences were largely ignored in the US national and state education standards (National Oceanic and Atmospheric Administration [NOAA], 2020; Ocean Literacy Network [OLN], 2015). The report indicated that ocean sciences were "an exciting context for teaching science and other disciplines in an integrated manner" (OLN, 2015). To help

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educators understand what essential concepts of ocean and climate science they should be teaching in their K-12 classes, the NOAA and the National Marine Educators Association (NMEA) developed the ocean and climate literacy guidelines (NOAA, 2020). While these guidelines can be achieved through traditional education (for access to specific lesson plans, see OLN, 2015), they are currently not being taught in several classrooms (Plutzer et al., 2016; Schoedinger et al., 2010). Our project, SVF, presents an informal learning experience that can complement formal classroom science learning. SVF is a Broadway-style musical theater STEAM (Science, Technology, Engineering, Arts, and Mathematics) experience coupled with hands-on activities geared to engage and educate elementary school students about ocean conservation and the climate change crisis using the ocean literacy goals. SVF is a university-led, collaborative effort led by a marine ecologist, an artist, and a science communication scholar, and was implemented with the help of trained undergraduates. This paper outlines the impact SVF had on the relationship to ocean and climate conservation among elementary school students who attended the program, their teachers, and the undergraduates who helped implement the program.

Theoretical foundations

The theoretical underpinning for implementing and assessing SVF is driven by the "theory of change for public engagement with science" (TCPES) put forth by the American Association for the Advancement of Science (AAAS), which provides

> a common framework, language, and research-based foundation for the many professionals involved in public engagement with science activities, and to serve as a starting point to enable scientists, practitioners, and researchers to continually improve and develop collective understanding of effective practices in public engagement with science. (AAAS, n.d.)

TCPES draws inspiration from theory of reasoned action, theory of planned behavior, and the integrated model of behavior change (AAAS, n.d.).

Theory of reasoned action posits that attitudes and norms affect behavioral intentions that then influence behavior change (Fishbein & Ajzen, 2010; Madden et al., 1992). Beliefs about a behavior affect whether an individual develops a positive/neutral/negative attitude about the new behavior, and norms are the beliefs about whether people in one's social network would approve of the new behavior (Fishbein & Ajzen, 2010). This theory suggests that both – attitudes and norms – affect the intention to change behavior that then affects the actual behavior (Fishbein & Ajzen, 2010; Madden et al., 1992). Theory of planned behavior posits that in addition to attitudes and norms, perceived behavioral control i.e. the perception of the ease/difficulty of performing the behavior will also affect the intention and the actual behavior (Ajzen, 1985; Madden et al., 1992; Wallston, 2015). The factor of perceived behavioral control is modified in the integrated model of behavior change to include self-efficacy i.e. how capable one feels about carrying out a behavior (Fishbein & Yzer, 2003; Wallston, 2015). The integrated model of behavior change expands on theories of reasoned action and planned behavior by proposing that in addition to one's behavioral intention (which is affected by attitudes, norms, and self-efficacy), their skill-level and environmental constraints can also determine whether or not a behavior will ultimately be carried out (Fishbein & Yzer, 2003). The integrated model of behavior change reminds us that although an individual can have an intention to perform a behavior (stemming from having a positive attitude, normative support, and high self-efficacy towards the new behavior), if they lack the skills to do it or have environmental constraints, they will not be able to adopt the new behavior (Fishbein & Yzer, 2003).

The goal of TCPES is to change behaviors among scientists, practitioners, and publics to engage with each other for the betterment of science and its policies. It recognizes that for public engagement to happen, every stakeholder involved (the scientists, practitioners, and publics) must improve their attitudes towards science and engagement. They must have a normative sense of appreciation for science and engagement, hone their perceived efficacy and skills to understand

and engage with science and each other, and work towards reducing constraints from any institutional structures to facilitate engagement (AAAS, n.d.). TCPES recognizes that the factors – attitudes, norms, efficacy, skills, constraints – will manifest and become more/less important depending on the stakeholder (AAAS, n.d.).

TCPES explicitly focuses on mutual learning, where an engagement results in all stakeholders learning from each other (AAAS, n.d.). For scientists/practitioners, it can involve learning how to engage with publics and how to learn from their experiential knowledge (AAAS, n.d.). For publics it can involve gaining three types of literacy: (i) practical literacy (i.e. conceptual understanding of science), (ii) civic literacy (i.e. the understanding of how to engage in deliberations involving science), and (iii) cultural literacy (i.e. the understanding to recognize and appreciate good science) (Shen, 1975).

Conceptual knowledge can improve through assimilation or accommodation (Piaget, 1952; Scott et al., 2014). When presented with new information, one can experience a "weak restructuring" of concepts where they are able to build on their prior knowledge and modify their understanding to assimilate new information into their existing schema (Carey, 1985; Scott et al., 2014). One can also experience a "strong restructuring" of concepts where they drastically change or add new concepts to accommodate their newly developed conceptual schema (Carey, 1985; Scott et al., 2014). These conceptual changes occur within one's cognition, but the process of knowledge construction is improved through interactive experiences where people are able to think and talk about these concepts with others, which is often enabled in informal learning spaces (Bell et al., 2009; Scott et al., 2014; Vygotsky, 1978).

Informal science learning spaces (such as aquariums, science centers, zoos, etc.) can help facilitate learning without the pressure of being traditionally assessed (Bell et al., 2009). These spaces can also cultivate a positive attitude through curiosity and excitement, a less stereotypical view to science/scientists, a sense of efficacy to learn/do science, and an identity with the scientific community which can potentially translate into STEM careers (Bell et al., 2009; Jensen & Buckley, 2012; Mares et al., 1999; Ruiz-Mallén et al., 2018).

Several informal science spaces have relied on arts to help improve engagement (see Dowell & Weitkamp, 2011; Drumm et al., 2013). Music especially has been found to make science learning enjoyable and effective (see, Emdin, 2010). Compared to non-musical methods of teaching, the repetition and rhythms in the musical teachings has been found to help with retention and improve conceptual understanding (Bower & Bolton, 1969; Calvert & Tart, 1993; Cirigliano, 2013; Crowther et al., 2016; Governor et al., 2013). SVF aims to provide a similar opportunity through its musical theater performance and interactive activities. These activities help students and teachers achieve the goals outlined by TCPES such as a better conceptual understanding of marine and climate science, a positive attitude towards conservation, an efficacy to help the environment, and develop a science identity. For the elementary school students, the goal is on improving their understanding and motivating them to adopt conservation behaviors. The goal for their teachers is to start engaging with their students on these topics without letting politics interfere. Lastly, the goal for the undergraduates is to encourage them to consider careers involving science communication and engagement. The program details, the involvement of audiences, and their assessments are outlined below.

About SVF

SVF took place in South Carolina (SC) from 30 January to 9 February 2019 and from 24 to 29 February 2020. SVF aims to teach NOAA's and NMEA's seven ocean literacy principles: (1) the Earth has one big ocean with many features, (2) the ocean and the life in the ocean shape the features of the Earth, (3) the ocean is a major influence on weather and climate, (4) the ocean made Earth habitable, (5) the ocean supports a great diversity of life and ecosystems, (6) the oceans and humans are inextricably connected, and (7) the ocean is largely unexplored (NOAA, 2020). SVF teaches these principles and their connections to climate change using a Broadway-style musical performance consisting of an amateur fisherman, a young scientist (based on real scientists working on this project), a seal, an octopus, a shark, a mother, and a child (see supplementary material for the narrative used in 2020).

Following the performance, elementary school teachers lead their students to several interactive stations presented by undergraduates who portray various careers:

1. A coral nursery showing how corals are grown and transplanted, followed by a coral health check and transplanting activity.
2. An underwater habitat where a researcher explains how scientists live and conduct research underwater and a dive master demonstrates SCUBA equipment, followed by a virtual dive activity.
3. A marine hospital (with live marine invertebrates in touch tanks) where a veterinarian explains how injured marine creatures are rescued, identified, and rehabilitated, followed by a marine species identification activity.
4. A beach and mangrove display where a park ranger explains the importance of beaches and mangroves and students explore a turtle nest and diorama.
5. A recycling center where the recycling process and the importance of waste reduction is explained, followed by a sorting and recycling activity.

There are also stations that are presented by artists and their teams:

1. A behind the scenes tour where the real stage director explains the theater production process, followed by question/answer time.
2. A meet-the-stars presentation where the actors demonstrate how to manipulate professional puppets, followed by a puppetry activity.

To the best of our knowledge, SVF is a unique STEAM effort that uses musical theater and interactive stations to tie a less controversial topic of ocean conservation with a relatively more controversial topic of climate change (see Kennedy, 2020). With several schools in SC slow to adopt the 2013 Next Generation Science Standards including climate change education (Kagubare, 2019; Plutzer et al., 2016), SVF offers a non-identity-threatening approach that uses storytelling and interaction to engage students and teachers in ocean and climate conservation. Given the importance of climate change to this next generation (Matkins & Bell, 2007) and the efficacy of how children's attitudes can affect adult attitudes on the subject (Larson et al., 2019; Valdez et al., 2017), SVF has potential to make an impact on environmental conservation. The goal of SVF is to not remain unique in its offering. Rather the program seeks to motivate more practitioners to design similar informal learning opportunities and to aid teachers to incorporate these approaches into their own classrooms. Thus, studying SVF and making our research visible is important to inform other informal efforts and related research involving environmental conservation.

Connecting theory to practice

SVF intends to engage with elementary school students, undergraduates, and elementary school teachers on helping them improve their relationship to marine and climate science, but each of the factors outlined in TCPES manifests and affects all three populations differently. As discussed earlier, TCPES states the goals of public engagement can involve improving factors such as conceptual understanding, attitudes, norms, efficacy, and intentions to continue their involvement with science and its policies (AAAS, n.d.). For this target group of elementary school students, we propose the following hypotheses:

H1: Elementary school children that experience SVF have a greater conceptual understanding of the ocean and climate in line with ocean literacy principles.

H2: Elementary school children that experience SVF have a positive attitude of curiosity and excitement towards engaging with our ocean and its creatures.

H3: Elementary school children that experience SVF have intentions to engage in ocean conservation.

H4: Elementary school children that experience SVF have an interest in science-based careers portrayed in SVF.

TCPES was developed to explain adult public engagement with science, where norms and efficacy could be measured relatively easily and accurately through surveys. However, with elementary school students, assessing the norms or efficacy of performing conservation actions will likely be tied with the norms and constraints set by their parents/guardians/teachers. Given how teachers will be helping elementary school students fill out their assessments, we decided to only hypothesize about their knowledge, attitudes of curiosity and excitement, and intentions. In the discussion section, we outline how our future work intends to measure these and other constructs of TCPES from students directly.

SVF also aims to help undergraduates develop a better relationship with science, by providing an opportunity to take on a kind of apprenticeship with the scientist and the artist. The undergraduates learn the language and practices of science from experts, and then teach them to the elementary school students (Lave & Wenger, 1991). This type of situated learning allows for undergraduates to feel a sense of belonging within the scientific community (Lave & Wenger, 1991; Scott et al., 2014). Students learn that norms within the scientific community also involve learning the civic and cultural aspects of science that translate into public engagement activities (Bell et al., 2009; Linvill et al., 2019). This is essential learning for a student who aims to pursue a career in science or science communication (AAAS, n.d.), but is equally valuable to a student who may pursue a career outside of science and remain engaged in scientific deliberations affecting policy as an informed citizen (Bell et al., 2009; Shen, 1975).

Applying TCPES to the expected outcomes of undergraduates in SVF, we investigate whether their knowledge of the science, attitudes towards learning/teaching science, norms associated with being a scientist i.e. a science identity, and an efficacy to engage with science and its communication, can affect their intentions to pursue careers involving marine science communication (that involves using technology, given how several of our stations involved technology-support) or science communication in general (AAAS, n.d.; Fishbein & Yzer, 2003; Jensen & Buckley, 2012; Linvill et al., 2019; Mares et al., 1999; Ruiz-Mallén et al., 2018). Thus, we propose the following research question.

RQ1: What characteristics outlined by TCPES will affect the interest of undergraduates to pursue a career involving (i) a marine science communication using some form of technology and (ii) science communication, in general?

The long-term goal of SVF is to equip teachers with the techniques used in our program to teach marine science and climate change in their own classrooms. Teachers have reported having little training in teaching climate change education (Kagubare, 2019; Plutzer et al., 2016). We want to assess if after attending SVF they feel better equipped to teach topics of ocean conservation and climate change in their classrooms, and if they will be interested in a workshop that teaches them how to draw connections between the two topics. As TCPES would indicate (AAAS, n.d.), these intentions could depend on their general attitude towards the science (which in this instance can be affected by their political ideology (see, Kennedy, 2020) or religiosity (see, Funk & Alper, 2015)), knowledge of marine and climate science, but also on the norms among teachers and their schools regarding being able to teach these topics in their classrooms. In this instance their ability to teach will likely depend more on them having the necessary knowledge and having the support of their colleagues and institutions, and relatively less of how individually capable they believe they can be at teaching these topics. Thus, we propose the following research question.

> RQ2: What characteristics outlined by TCPES will affect the intentions of elementary school teachers to (i) teach marine science in their classrooms, (ii) teach climate change in their classrooms, and (iii) participate in a teacher training program connecting marine science and climate change education?

Methods

To assess the impact of SVF on elementary school students, undergraduates, and elementary school teachers we employed different instruments.

Elementary school students

Information about participating in SVF was shared with elementary school administrations and their teachers by making phone calls and sending emails. SVF reached out to elementary schools in Anderson, Oconee, and Pickens counties of South Carolina. These counties were the most proximal to where SVF was being hosted. Approximately 60 classes from 13 elementary schools attended SVF. Printed workbooks were provided to all elementary school teachers who brought their students to SVF. A total of 49 completed workbooks with a signed parental consent forms were returned. Parents were informed that no other data except for their child's first name (to keep track of their workbooks) would be gathered and only "changes in study populations not specific individuals" will be collected or reported. Of the 49 students, 10 belonged to a kindergarten class at a public school in Anderson county, 24 students from grade 2 belonged to two separate classes of the same public school in Oconee county, and the 15 students from grade 4 belonged to a public school in Anderson county.

The workbooks contained: (1) a page asking students to draw what they see under the ocean and provide a brief explanation of their drawing, (2) a page asking students to circle pictures of 3 future careers from 24 options (3) a "think-feel-do" page, asking students to report their feelings towards seeing, playing, and meeting ocean creatures, their attitudes towards conservation, and (4) a list of actions they intend to or already do to help the oceans. The three pages mentioned above were provided twice in the workbook, to be filled out both before and after attending SVF and were separated by several pages of marine science-based puzzles and drawings.

Drawings have been used as an assessment tool to study how children feel about science and scientists (Chambers, 1983; Farmer et al., 2018). We applied a similar strategy to assess how the elementary school students perceived oceans before and after the show. Tables 1–4 indicate the measures and their respective codes. Table 1 indicates the codebook that includes measurements to assess the elementary school students' conceptual understanding by analyzing the constructs they drew, if they were inspired by SVF, and if they were portraying a positive/neutral/negative scenario. Table 2 indicates the codes for each of the 24 careers provided. Table 3 indicates the codes and items that measured curiosity and excitement the elementary school students felt about learning and engaging with the ocean and its creatures (Figure 1). Table 4 indicates the codes that measured the elementary school students' intended ocean conservation behaviors. These were coded for the pre-show and post-show responses in the workbooks.

Undergraduates

The undergraduates received credit for participating in SVF and for taking the survey after concluding SVF for the year. Their responses were anonymous. They all encountered three attention-check questions, at three different points in the survey, asking them to select a specific option to indicate that they were paying attention. For example, one of the questions stated, "I am paying attention to this survey and to show that I need to select 'strongly agree' for this statement." Two other questions

Table 1. Codebook measures – conceptual understanding.

Description (code)
Construct: Please enter one of the following numbers below in the column "construct" to indicate what elements are present in the drawing. [Note: Ocean here includes plant-life with it. Human-used products can include scuba gear, fishing, trash, boats, submarines. etc.]
• Ocean without sea animals, humans, or human-used products (1)
• Ocean with only sea animals (2)
• Ocean with only human beings (3)
• Ocean with only human-used products
• Ocean with sea animals and humans (5)
• Ocean with humans and human-used products for the ocean (6)
• Ocean with sea animals and human-used products (7)
• Ocean with sea animals, humans, and human-used products (8)
Centricity: Please indicate the number assigned for the code below to indicate if you notice that the drawing has any of the following centricity options
• SVF: You can identify if the drawing is centered around specific scenes of SVF. If you see a red boat or one/few of the animals with nothing about a specific scene from the show, then do not code it SVF. We want to measure if children learned the key messages from the show in this code for SVF. (1)
• Popular culture: You can identify if the drawing is centered around movies depicting underwater life such as Finding Nemo, Finding Dori, Spongebob, Shark Tales (maybe before that time), Jaws, Fish Hooks, Little Mermaid, Moana, Pirates of the Caribbean, Titanic, etc. (2)
• No centricity (3)
Scenarios: Please enter one of the following numbers below in the column "scenario" to indicate the overall message in the drawing being depicted
• Positive/neutral scenarios: A positive scenario could include (but not limited to) some of the following situations. The overall goal of a positive/neutral scenario is to indicate that the child's drawing is showing a positive/neutral state of the oceans and/or how humans are interacting with each other or with animals in that environment. The analysis is from an ecological perspective. [Examples: No trash in the picture, and if there is trash then it appears that people are picking up trash or taking care of it, natural interactions of predator-prey, etc.] (1)
• Negative scenario: A negative scenario could include (but not limited to) some of the following situations. The overall goal of a negative scenario is to indicate that the child's drawing is showing a negative state of the ocean and/or how humans are interacting with each other or with animals in that environment. [Examples: Trash or man-made materials injuring animals or entrapping them in some way, Humans killing animals with spears, guns, any other object that is not intended for fishing] (2)
Colors: Please use the assigned code below to indicate the color of the drawing
• One color only, with pencil only i.e. black and white (1)
• One color only, with a color other than the regular pencil i.e. not black and white (2)
• More than one color (3)

similarly stated were asked at different points in the survey. Of the 53 students who took the survey, 40 passed all three attention-checks. Of those 40 students, 37 identified as female, and 33 identified themselves as Caucasian/White. The average age of the students was 20. Fifteen participated in SVF previously.

Table 5 indicates the items used to measure their perceived knowledge, perceived efficacy to engage with science and its communication, attitude towards science, science identity, and their

Table 2. Codebook measures – careers.

Career (code)	Career (code)
Coral scientist (1)	Marine biologist (13)
Doctor (2)	Robot designer (14)
Movie star (3)	Nurse (15)
Actor (4)	SCUBA diving instructor (16)
Boat captain (5)	Painter (17)
Police officer (6)	Fireman (18)
Musician (7)	Science teacher (19)
Audio engineer (8)	Park ranger (20)
Nature photographer (9)	Animal veterinarian (21)
Seafood market owner (10)	Singer (22)
Writer (11)	Fisherman (23)
Video game designer (12)	Playwright (24)

Note: Coder used assigned code below to indicate the careers selected.

Table 3. Codebook measures – think, feel, do.

Description (code)
How do you feel about going to see a play about the ocean and ocean creatures?
Saddest face (1)
Somewhat sad face (2)
Neutral face (3)
Somewhat happy face (4)
Happy face (5)
How do you feel about going to meet small creatures that live in the ocean?
Saddest face (1)
Somewhat sad face (2)
Neutral face (3)
Somewhat happy face (4)
Happy face (5)
How important do you think the ocean and ocean creatures are to you?
Smallest dot (1)
Second smallest dot (2)
Middle dot (3)
Second largest dot
Largest dot (5)
How much do you want to help the ocean and ocean creatures?
Smallest dot (1)
Second smallest dot (2)
Middle dot (3)
Second largest dot (4)
Largest dot (5)

Note: Figure 1 shows how the options for these items were shown in the workbook.

Table 4. Codebook measures: ocean conservation intentions and behaviors.

Description
Use a reusable water bottle
Take reusable shopping bags to the store
Recycle at home
Turn out lights when you leave a room
Don’t leave tap running when I brush my teeth
Don’t litter
Have a quick shower
Pick up other people’s trash
Other
Other – text response

Note: Same set of items were provided for questions: (a) What things do you do at home or school that helps the ocean and ocean creatures? (b) Which of these things would you want to do to help the ocean and ocean creatures? Code – 1 if they were marked, 0 if left empty.

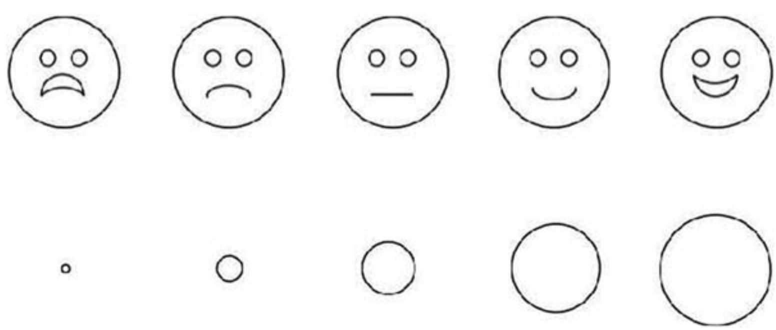

Figure 1. Scales related to Table 3.

intentions to pursue a career involving communication. Items were generated based on previous works (see, Besley et al., 2018; Hanauer et al., 2017; Linvill et al., 2019; Poliakoff & Webb, 2007; Shanahan, 2009; Tonso, 2014).

Elementary school teachers

Elementary school teachers who brought their students to SVF were incentivized with a $25 gift card to participate in the survey. Of the 35 teachers who took our survey, 27 teachers passed all three attention-checks. The attention-checks were similar to the ones described in the previous section. Of those 27 teachers, 25 were female and were on average 38 years old ($M = 38.41$, SD = 10.26). Political ideology was measured on a 5-point scale (1 = very conservative to 5 being very liberal) and most identified as either very or somewhat conservative ($M = 2.33$, SD = 1.04). On average, these teachers attended religious services (apart from weddings or funerals) 2–3 times a month ($M = 4.04$, SD = 1.79).

Table 6 indicates the items used to measure their perceived knowledge, attitude towards science, descriptive norms (i.e. perceptions of what most teachers do), injunctive norms (i.e. perceptions of other teachers' approval), intentions to teach marine science and climate change, and intentions to participate in a teacher training workshop to prepare teaching climate change using marine science. Items were generated based on previous works (see, GSS, n.d.; Plutzer et al., 2016; Tallapragada et al., 2017).

Results

Elementary school students

Student drawings were content analyzed using the codebook (see Table 1), which was coded first, by three undergraduate student coders and then, by three graduate student coders. Some sample

Table 5. Undergraduate student survey measures.

Perceived knowledge (1 = nothing at all to 5 = a great deal)
How much do you know about marine science?
Efficacy (Scale: 1 = strongly disagree to 5 = strongly agree)
I am confident that I can take more creative/research-based classes that involve marine sciences
I am confident that I can find resources to help me keep up with learning more about marine science
I am confident in my ability to communicate about marine science to my friends and family
I am confident in designing a VR experience on ocean literacy
Prior to enrolling in this class, I had learnt to design a VR experience
I am confident that I can engage in stewardship behaviors to help the oceans
I am confident in helping children use VR to learn about oceans
I am confident that I can take more such creative/research-based classes that involve science in general.
Cronbach's alpha = 0.74
Attitude towards science (Scale: 1 = strongly disagree to 5 = strongly agree)
I feel discovering something new in science is thrilling
I think science can solve many of today's world's challenges
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
Cronbach's alpha = 0.92
Science identity (Scale: 1 = strongly disagree to 5 = strongly agree)
The work of a science student is appealing to me
I have a duty as a student to take part in science communication activities targeting the general public including children
I have come to think of myself as a science student
I feel like I belong in the field of science
I derive great personal satisfaction from working on a team that is doing important scientific work such as SVF
I have a strong sense of belonging to the science community
Cronbach's alpha = 0.91
Career Interests (Scale: 1 = strongly disagree to 5 = strongly agree)
I am interested in a career that involves using technology such as VR to communicate marine science
I am interested in a career that involves science communication

Table 6. Elementary school teacher survey measures.

Perceived knowledge: (1 = nothing at all to 5 = a great deal)
Rate your level of understanding of the following …
Marine science
Climate change
Connection between climate change and marine science
Attitude towards science (Scale: 1 = strongly disagree to 5 = strongly agree)
Because of science and technology, there will be more opportunities for the next generation
Science makes our way of life change too fast
Even if it brings no immediate benefits, scientific research that advances the frontiers of knowledge is necessary and should be supported by the federal government
Scientific researchers are dedicated people who work for the good of humanity
Most scientists want to work on things that will make life better for the average person
Scientists are helping to solve challenging problems
Scientists are apt to be odd and peculiar people
Cronbach's alpha = 0.73
Descriptive norms (Scale: 1 = strongly disagree to 5 = strongly agree)
(similar items were asked to measure descriptive norms for teaching climate change)
The teachers I work with, who are important to me, would care about teaching ocean conservation
The teachers I work with, who are important to me, would teach ocean conservation
Cronbach's alpha (ocean conservation) = 0.72; Cronbach's alpha (climate change) = 0.96
Injunctive norms (Scale: 1 = strongly disagree to 5 = strongly agree)
(similar items were asked to measure injunctive norms for teaching climate change)
The teachers I work with, whose opinions I value, would expect me to teach ocean conservation
It is expected of me to teach ocean conservation,
The people I work with, whose opinions matter to me, would approve of me teaching ocean conservation
Cronbach's alpha (ocean conservation) = 0.75; Cronbach's alpha (climate change) = 0.63
Intentions to teach (Scale: 1 = strongly disagree to 5 = strongly agree)
In the future, I plan to teach …
Marine science
Climate change
Intention to participate in (Scale: 1 = extremely likely to 5 = extremely unlikely)- recoded
A teacher training workshop to prepare teaching climate change using marine science

drawings are attached in the Appendix. The undergraduate student coders began by coding a sample set of five drawings gathered from our pretest of the SVF codebook to establish intercoder reliability collected during the 2019 SVF shows. The pretest consisted of five full sets of workbooks analyzed before and after SVF. They assessed: constructs (Krippendorf's alpha = 0.76), centricity (Krippendorf's alpha = 0.62), scenarios (Krippendorf's alpha = 0.61), and the colors used in the drawing (Krippendorf's alpha = 1). In this pretest set, the workbooks did not ask for the students to describe their drawings. To improve the validity and reliability of these conceptual understanding items, in 2020 we asked students to describe their drawings. Three graduate students used the latest codebook (see Tables 1–4) to code 7 workbooks and achieved agreement on all variables after two rounds of training. All the workbooks that included the before and after measures of SVF in 2020 were coded using the latest codebook, first by the undergraduates and then by the graduate students to ensure quality control during coding.

A series of paired t-tests were conducted on the following analyses. There was a significant decrease ($t(48) = 3.85$, $p < 0.001$) in students drawing oceans with only sea animals in the pre-show drawings ($M = 0.67$, SD = 0.47) to the post-show drawings ($M = 0.33$, SD = 0.47). There was a significant increase ($t(48) = -4.12$, $p < 0.001$) in students drawing ocean with sea animals and human-used products from the pre-drawings ($M = 0.16$, SD = 0.37) to the post-show drawings ($M = 0.49$, SD = 0.51). Overall, there was a significant increase in how children viewed under the ocean from being predominantly about sea animals before the show to including human-used products after the show. While no one had SVF centricity in their pre-show drawings, there were seven post-show student drawings that had an SVF-related scene.

There was a significant decrease ($t(48) = 5.51$, $p < 0.001$) in students drawing positive/neutral scenarios before the show ($M = 0.88$, SD = 0.33) to after the show ($M = 0.49$, SD = 0.51). There was a significant increase ($t(48) = -5.51$, $p < 0.001$) in students drawing negative scenarios before

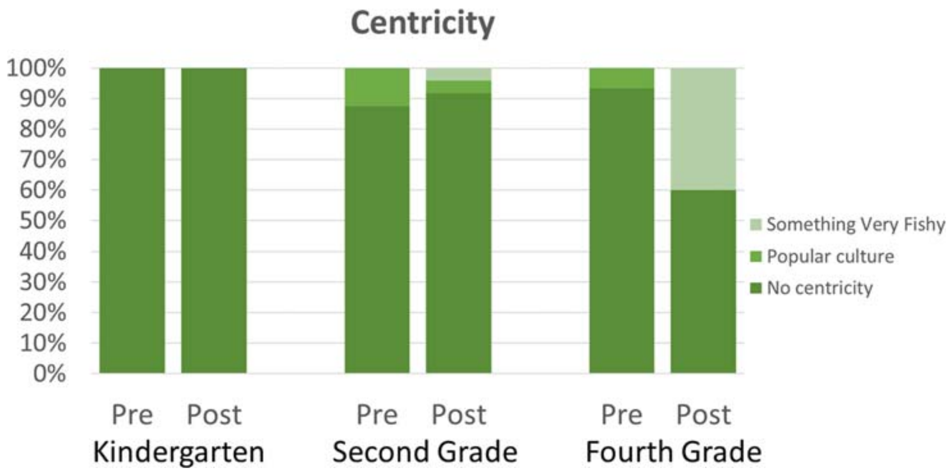

Figure 2. Percent of children's drawings scored for three measures of content centricity before (pre) and after (post) attending SVF for students in kindergarten ($N = 10$), second grade ($N = 24$), and fourth grade ($N = 15$).

the show ($M = 0.12$, SD = 0.33) to after the show ($M = 0.51$, SD = 0.51). There was no significant difference in the number of colors students used before to after the show. Students in each grade that belonged to a different school showed significant differences in their distributions of drawing scores for centricity (Figure 2: $\chi^2 = 13.74$, $df = 4$, $p = 0.0081$), constructs (Figure 3: $\chi^2 = 22.79$, $df = 6$, $p = 0.0009$), colors (Figure 4: $\chi^2 = 12.29$, $df = 4$, $p = 0.0153$), and scenarios (Figure 5: $\chi^2 = 24.79$, $df = 2$, $p < 0.0001$).

There was no significant difference among student's feelings towards going to see a play on ocean and ocean creatures, in enthusiasm for meeting ocean animals, or in their feelings about caring for or helping the ocean. It must be noted that all pre-show measures of playing with ocean creatures ($M = 4.51$, SD = 0.92), meeting ocean creatures ($M = 4.45$, SD = 1.04), importance of ocean health ($M = 4.49$, SD = 1.21), and wanting to help our oceans ($M = 4.41$, SD = 1.27) were all high, to begin with. These measures continued to be similar after the show, respectively for playing with ocean creatures ($M = 4.31$, SD = 1.54), meeting ocean creatures ($M = 4.14$, SD = 1.61), importance of ocean health ($M = 4.20$, SD = 1.65), and helping oceans ($M = 4.20$, SD = 1.58). Fewer children

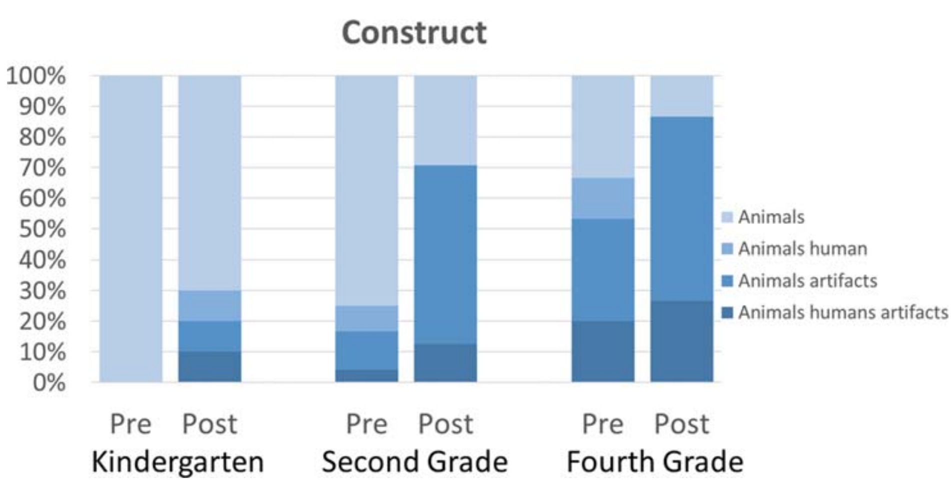

Figure 3. Percent of children's drawings scored for four measures of content construct before (pre) and after (post) attending SVF for students in kindergarten ($N = 10$), second grade ($N = 24$), and fourth grade ($N = 15$).

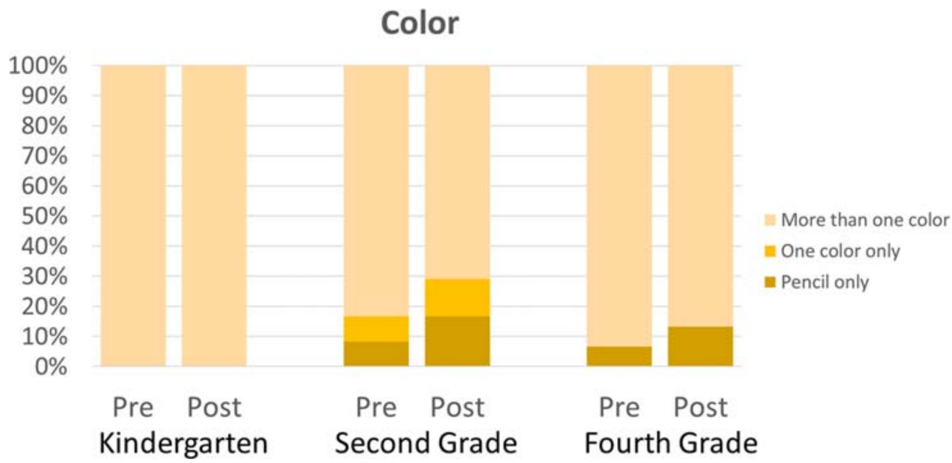

Figure 4. Percent of children's drawings scored for three measures of content color before (pre) and after (post) attending SVF for students in kindergarten ($N = 10$), second grade ($N = 24$), and fourth grade ($N = 15$).

expressed that they would "pick up other people's trash" ($t(48) = 2.64$, $p < 0.05$) from before the show ($M = 0.74$, SD = 0.45) to after the show ($M = 0.55$, SD = 0.50).

There were eight careers which were science-based careers: coral scientist, doctor, audio engineer, marine biologist, robot designer, nurse, science teacher, animal veterinarian. Of which, four were portrayed in SVF: coral scientist, audio engineer, marine biologist, and animal veterinarian. While there was no significant difference between students wanting to pursue the eight science careers as a whole, there was a significant increase ($t(48) = -4.48$, $p < 0.001$) in students choosing the four science careers portrayed in SVF from before the show ($M = 0.35$, SD = 0.48) to after the show ($M = 0.51$, SD = 0.51). There was also a significant decrease in the art careers chosen ($t(48) = 2.27$, $p < 0.05$) from before the show ($M = 0.71$, SD = 0.46) to after the show ($M = 0.53$, SD = 0.50). Because students could only choose three careers, a shift in choosing more science careers meant there would be a decrease in choosing art careers.

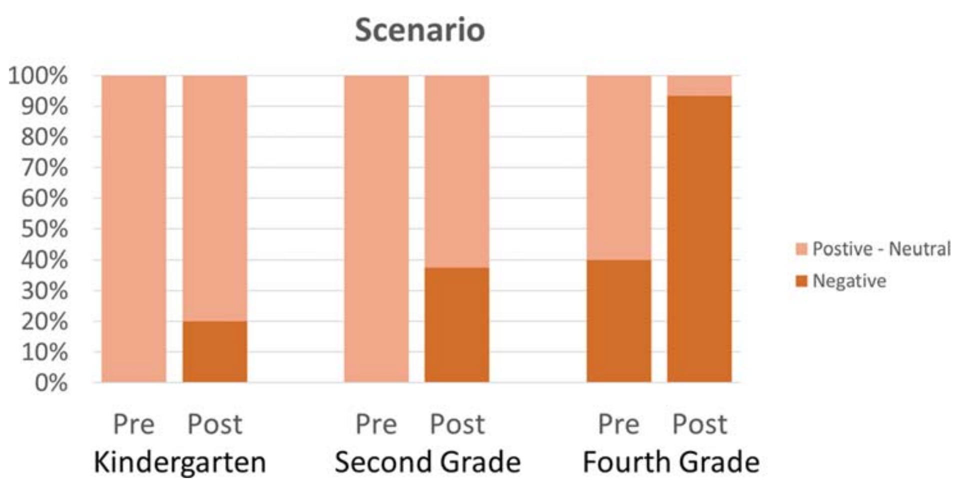

Figure 5. Percent of children's drawings scored for two measures of content scenario before (pre) and after (post) attending SVF for students in kindergarten ($N = 10$), second grade ($N = 24$), and fourth grade ($N = 15$).

Table 7. Linear regressions for undergraduates addressing RQ1 and RQ2.

Predictor	Career in marine science communication involving technology		Career in science communication (in general)	
	B	S.E	B	S.E.
Intercept	−4.92	18.58	−0.17	18.08
Gender (female)	−0.66	0.66	0.53	0.64
Age	0.04	0.19	−0.04	0.18
Returned to SVF	0.01	0.40	0.03	0.39
Perceived knowledge	−0.45	0.28	−0.31	0.27
Perceived efficacy	0.87*	0.40	0.37	0.39
Attitude towards science	0.60	0.40	0.35	0.37
Science identity	0.01	0.38	1.05**	0.37
R^2	0.41	–	0.63	
$R^2_{adjusted}$	0.26	–	0.54	

***$p < 0.001$; **$p < 0.01$; *$p < 0.05$.

Undergraduates

The undergraduates were primarily involved in handling stations of marine science and reported having some or a moderate level of understanding of marine science ($M = 3.10$, SD = 0.78). They reported having a somewhat high level of efficacy in engaging with marine science and its communication ($M = 4.15$, SD = 0.56). They reported a neutral attitude towards science ($M = 3.29$, SD = 0.83). Finally, they indicated a somewhat high science identity ($M = 4.3$, SD = 0.78). There was interest in students wanting to engage in activities that would help ocean health, but not as a career ($M = 4.35$, SD = 0.83). Some students were interested in careers of marine science communication using technology ($M = 2.38$, SD = 1.13) and science communication in general ($M = 3.15$, SD = 1.37).

We conducted linear regressions (as shown in Table 7) to assess if perceived knowledge, attitude towards science, science identity, or perceived efficacy influenced their career choices. After controlling for age, gender, and whether or not they were returning students, those who perceived more efficacy towards marine science and its communication ($B = 0.87$, S.E. = 0.40, $p = 0.04$) were more likely to express an interest in pursuing a career in marine science communication involving technology ($R^2 = 0.41$, $R^2_{adjusted} = 0.26$). Similarly, after controlling for age, gender, and whether or not the student returned to SVF, those who experienced a sense of science identity ($B = 1.05$, S.E. = 0.37, $p < 0.01$) were more likely to express an interest in a general science communication career ($R^2 = 0.63$, $R^2_{adjusted} = 0.541$).

Elementary school teachers

Teachers indicated having a somewhat positive attitude towards science ($M = 4.13$, SD = 0.41). They indicated having some understanding of marine science ($M = 3.04$, SD = 0.76) and climate change ($M = 2.85$, SD = 0.77). With respect to norms, they perceived that their fellow teachers would somewhat care about teaching ocean conservation ($M = 3.93$, SD = 0.69) and felt that there was some expectation to teach ocean conservation ($M = 3.21$, SD = 0.91). Similarly, they perceived that their fellow teachers would somewhat care about teaching climate change ($M = 3.82$, SD = 0.92) and felt there was some expectation to teach climate change (M = 3.09, SD = 0.89).

Of the 27, 4 teachers reported teaching both climate change and ocean conservation, 2 reported teaching climate change but not ocean conservation, and 4 teachers reported teaching only ocean conservation. Thus, a total of 6 teachers reported teaching climate change and 8 teachers reported teaching ocean conservation. A total of 16 teachers reported that they do not teach either climate change or ocean conservation. A total of 25 teachers reported teaching using arts and 19 reported teaching science using arts, which indicates their skill and comfort with using arts in their teaching.

Table 8. Linear regressions for elementary school teachers addressing RQ3, RQ4 and RQ5.

	Intention to teach marine science		Intention to teach climate change		Intention to participate in teacher training	
Predictor	B	S.E.	B	S.E.	B	S.E.
Intercept	4.37	2.13	0.59	1.81	−0.23	2.12
Age	−0.01	0.02	−0.00	0.02	−0.02	0.02
Ideology (liberal)	0.12	0.21	0.26	0.19	0.40	0.21
Religiosity	−0.14	0.12	0.08	0.11	0.13	0.13
Attitude towards science	−0.28	0.51	−0.10	0.47	0.59	0.53
Perceived marine science knowledge	−0.24	0.26	–	–	−0.34	0.32
Perceived climate change knowledge	–	–	−0.08	0.26	−0.20	0.33
Descriptive norm: ocean conservation	−0.10	0.30	–	–	−0.61	0.46
Injunctive norm: ocean conservation	0.67*	0.26	–	–	0.90*	0.36
Descriptive norm: climate change	–	–	0.29	0.23	1.16**	0.34
Injunctive norm: climate change	–	–	0.61*	0.27	−0.82	0.40
R^2	0.37	–	0.58	–	0.69	–
R^2_{adjusted}	0.14	–	0.43	–	0.50	–

***$p < 0.001$; **$p < 0.01$; *$p < 0.05$.

With regards to future plans, more teachers planned to teach marine science ($M = 3.81$, SD = 0.83) and climate change ($M = 3.74$, SD = 0.98) in their classrooms. Most teachers also expressed their likelihood of participating in a teacher training workshop to teach climate change using marine conservation ($M = 3.63$, SD = 1.08).

We conducted linear regressions (as shown in Table 8). After controlling for age, ideology, and religiosity, teachers who expressed an intention to teach marine science in the future ($R^2 = 0.37$, $R^2_{\text{adjusted}} = 0.14$), were those who perceived that their fellow teachers would expect and approve of them teaching marine science in their classrooms ($B = 0.67$, SE = 0.26, $p = 0.017$). After controlling for age, ideology, and religiosity, teachers who expressed an intention to teach climate change in the future ($R^2 = 0.58$, $R^2_{\text{adjusted}} = 0.43$), were those who perceived that their fellow teachers would expect and approve of them teaching climate change in their classrooms ($B = 0.61$, SE = 0.27, $p = 0.04$). After controlling for age, ideology, and religiosity, the teachers who expressed an intention to participate in a teacher training workshop to prepare teaching climate change using marine conservation (R^2=0.69, $R^2_{\text{adjusted}} = 0.50$), were those who perceived that their fellow teachers would expect and approve of them teaching marine science in their classrooms ($B = 0.90$, SE = 0.34, $p = 0.02$) and perceived that fellow teachers would also teach climate change in their classrooms ($B = 1.16$, SE = 0.34, $p < 0.01$).

Discussion

This study investigated the effects of SVF, a Broadway-style musical theater STEAM experience, on elementary school children, undergraduate students, and elementary school teachers. Below we discuss our program implications and connect our findings to TCPES.

Program implications

Results indicated that the elementary school students who attended SVF showed an improvement in their conceptual understanding related to two ocean literacy principles; the oceans contain a diversity of life and ecosystems, and oceans and humans are connected in their actions and consequences (NOAA, 2020). Thus, H1 was supported. The students succeeded in understanding the harm that lack of conservation can do to the environment. The learning seems to have occurred through the process of accommodation by developing a new schema around oceans and their conservation (Scott et al., 2014). An increase in conceptual understanding, however, did not translate to an increase in curiosity, excitement, or intentions to engage in ocean conservation, thus not supporting H2 and H3. SVF was successful in motivating the elementary school students to become interested in the science careers that were portrayed in the show and at the stations, which supported H4.

The undergraduates were involved from the making to the implementation stages of SVF. Using various forms of technology, the undergraduates were the front-line of engagement for all elementary school children at various stations. They were responsible for explaining the station and answering questions the children had about the science or the show. In the process of these engagements, they were also apprentices who were learning marine science and methods of public engagement (Lave & Wenger, 1991; Scott et al., 2014). The findings of our study helped SVF answer RQ1 by showing that a sense of efficacy and science identity among the undergraduates nurtured through SVF, and can translate into wanting to pursue careers that involve science communication and public engagement.

The study also provided a baseline assessment for how teachers perceive topics of ocean conservation and climate change in parts of South Carolina. Several state curriculums do not necessitate climate change education. On 3 June 2020, New Jersey became the first state to announce that their public schools from K-12 will include climate change education (State of New Jersey, 2020), which leaves several states with no expectations from authorities or peers to teach these topics. Our results helped answer RQ2 by indicating that either formal expectations or informal norms need to be set in place to encourage teachers to instruct ocean and climate science in their classrooms.

Connecting findings to TCPES

This study used TCPES as a guide to study the impact of public engagement through an informal STEAM program among children and adults. Although TCPES was designed for adults and not for children, this study showed that the theoretical framework of TCPES can be applied using existing literature of science communication and education to implement and assess informal STEAM projects.

This study demonstrated that SVF could help attain some of the outcomes for successful engagement as defined by TCPES (AAAS, n.d.) such as, improving conceptual understanding and increasing interest in the STEM workforce among elementary school students (i.e. confirming H1 and H4), and contributing to a sense of efficacy, nurturing a science identity, and fostering a willingness to consider engaging in science-society interactions among undergraduates (i.e. answering RQ1). TCPES also identifies institutional support as being a contributing factor for facilitating engagement with science (AAAS, n.d.). Our study showed how important this support can be for elementary school teachers in fostering norms (i.e. answering RQ2). They need institutions such as their state and schools to set clear and formal expectations about teaching ocean and climate science in their classrooms (AAAS, n.d.). Until these formal changes occur, programs such as SVF that pair with classroom teachings can be crucial for meeting the ocean literacy standards.

As discussed above, SVF was successful in achieving some but not all TCPES outcomes. The study shows that TCPES goals are unlikely to be uniformly distributed among multiple stakeholders. Although TCPES provides a range of potential outcomes from engagement, every program should take steps to prioritize their outcomes and investigate why some were achieved while others were not. For example, H2 was not supported in this study i.e. among the elementary school students, there was no significant increase in curiosity or excitement to engage with ocean creatures, because the students were highly excited and curious before coming to SVF and continued to be so throughout the program. Although this may seem like a TCPES goal was not achieved, the result indicates that the program did well to keep up the levels of excitement and curiosity. On the other hand, H3 was not supported i.e. there was no significant increase in intentions to conserve among the elementary school students, which was a key outcome the program was hoping to achieve. These non-significant results together highlight the importance of assessing TCPES goals before individuals begin their engagement to help practitioners and scholars plan which goals should take precedence over others in their program.

Future directions and conclusions

SVF aims to address its current limitations in its next version and hopes that it inspires other informal experiences that can help generate knowledge and practice of environmental conservation. Moving forward, we will increase our recruitment efforts to test the replicability of our findings from this study. We intend to have more grades from the same elementary schools participate, and design different workbooks that will engage students based on their grade levels. This will help assess if type of school or grade affects the impact of SVF. We will also collect information of the student's age, gender, and race to investigate how these demographic factors might affect their responses. The next version of the workbooks will also have more specific questions to assess the curiosity and excitement around specific experiences shown in SVF. Instead of giving a list of intended actions, in the next version, we will ask an open-ended question to gauge how they would choose to help the ocean in their own ways. To measure the perceived norms, we will ask these children what they observe with respect to conservation behaviors in their homes and schools. We will also initiate interviews or focus groups with students to gain a deeper understanding of their responses.

The changes observed in this study can be short-lived and could have been a result of an availability bias (i.e. tendency to think of what is most available in the memory, often driven by the most recent experience (Kahneman, 2011)). We intend to conduct longitudinal studies to assess the impact of SVF over time among the elementary school students as they move through each grade and among the undergraduates even after they graduate.

Involving teachers will be essential, as the lessons taught via an informal experience, can be fortified and made more meaningful when they are taught in conjunction with formal education (see, CAISE, 2010). We intend to engage with teachers individually through surveys and interviews, but also through focus groups to understand their perceived norms and discuss potential obstacles and opportunities for SVF to get involved to help meet their ocean literacy goals.

SVF now includes an alternative online format due to the COVID-19 pandemic. With the help of our undergraduates, we conducted several synchronous interactions and shared asynchronous learning materials with the elementary school teachers and their students. We intend to assess the impact of virtual SVF on TCPES measures among the elementary school students, their teachers, and the undergraduates involved in our future work.

It is also important for future work to build on the TCPES framework. For example, future research should develop methods and measures to specifically assess children's engagement with science through informal STEAM efforts can improve knowledge, curiosity, excitement, intentions, and actions for conservation. Future directions should also include an assessment of how science identity as outlined by TCPES can be nurtured or transformed through informal STEAM opportunities among undergraduates who pursue STEM or non-STEM careers (AAAS, n.d.). Studies should also analyze how norms and efficacies among teacher could be related, and how their group efficacy (i.e. a perceived capability as a group) may be related to their individual efficacy (i.e. each teacher's perceived capability) around teaching ocean and climate conservation (Gibson et al., 2000).

SVF will need the support of several complementary programs to ensure that the messages of environmental conservation are nurtured with several repetitive and complementary engagement activities. We urge practitioners and researchers to implement and assess their STEAM efforts to help us improve our individual programs, contribute to the theoretical foundations that inspire environmental conservation, and help achieve the goals of public engagement with science among children and adults.

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Appendix

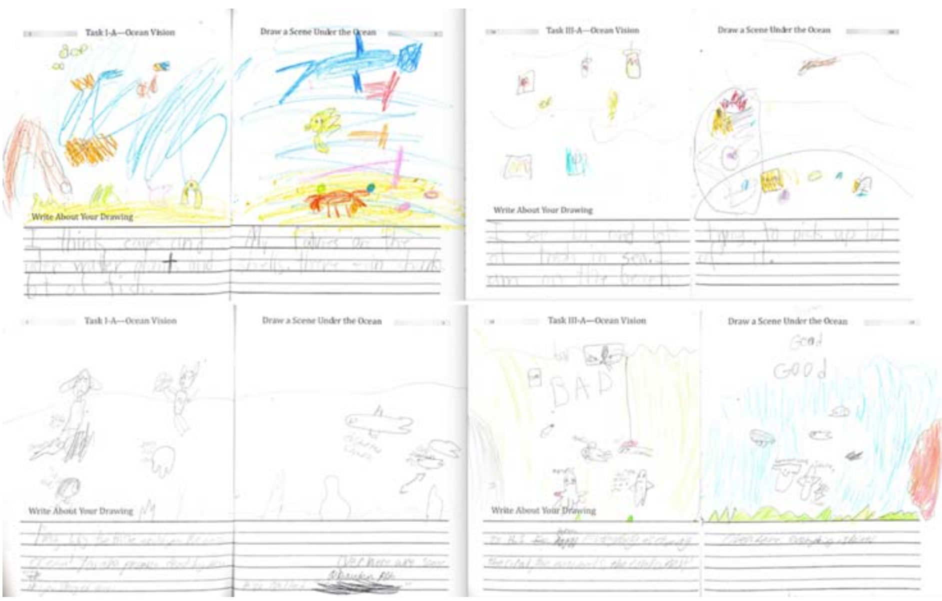

Figure A1. Pre and post drawings of student A (top) and student B (down).