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University of Maine, gabrielle.brodek@maine.edu

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YOUTH'S EXPRESSIONS OF PERSONAL SIGNIFICANCE IN AN INFORMAL LEARNING SETTING THAT BRIDGED STEM AND EXPERIENTIAL LEARNING

By

Gabrielle Brodek

B.S. Environmental Science, Drake University, 2017

A THESIS

Submitted for Partial Fulfillment of the

Requirements for the Degree of

Master of Science

(in Teaching)

The Graduate School

The University of Maine

May 2022

Advisory Committee:

Elizabeth Hufnagel, Associate Professor of Science Education

Vanessa Klein, Assistant Extension Professor, 4-H STEM Specialist, Assistant Professor of Ed.

Asli Sezen-Barrie, Associate Professor of Curriculum, Assessment and Instruction

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By Gabrielle Brodek

Advisor: Elizabeth Hufnagel

An Abstract for the Thesis Presented

in Partial Fulfillment of the Requirements for the

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May 2022

When youth relate to environmental science on a deep, personal level they are more likely to retain information, as they make neural connections to significant lived experiences, and are more likely to be environmentally aware and engage in actions that benefit marine and freshwater ecosystems. In order to promote and encourage personally significant connections to environmental science ideas, tools, and practices, it's important to design a curriculum or program that provides opportunities for reflection, discussion, and application. This thesis includes one practitioner manuscript that describes the development of a new design process for informal learning programs that incorporates evidence-based STEM instruction through the 5E Instructional Model, and best-practices of informal teaching through the 4-H adapted

Experiential Learning Model. The design overlaps the two models, highlighting the ways the learning models both supplement and complement each other, which was created during the development of a 4-H Science Toolkit about sustainable fishing. With an emphasis on reflection, 21st century life skills, and socio-emotional learning, the sustainable fishing curriculum made space for opportunities for youth to express personally significant experiences, and use them to connect with environmental science ideas, tools, and practices. The empirical manuscript shared in this thesis highlights the ways four youth participants expressed personal significance about their appreciation and fascination of nature experiences, experiences with family and around place, and about a change of perspective in an after-school program that presented the 4-H Toolkit sustainable fishing curriculum. By taking a sociolinguistics approach, the sharing of these personally significant experiences made salient how youth were connecting to scientific tools, ideas, and practices on a deeply, personal level in the moment-to-moment interactions in the discourse of the after-school program.

TABLE OF CONTENTS

LIST OF TABLES……………………………………………………………………......……iv

LIST OF FIGURES……………………………………………………………....………….v

INTRODUCTION………………………………………………………………...…………1

Chapter 1: BETTER TOGETHER: BRIDGING STEM AND EXPERIENTIAL

LEARNING TO IMPROVE INFORMAL EDUCATION PROGRAMS…...….……....4

Chapter 2: "YOU WON'T BELIEVE WHAT YOU SEE!": YOUTH'S EXPRESSIONS

OF PERSONAL SIGNIFICANCE IN AN AFTER-SCHOOL CLUB ABOUT

SUSTAINABLE FISHING.………………………………………………………29

CONCLUSION…………………….…………………………..………………...…………55

REFERENCES…………………..………………………….………………...………...….57

APPENDIX: TRANSLATION CONVENSIONS……….…………………………...……..…64

BIOGRAPHY OF THE AUTHOR………………..……..…..……………………..….…65

LIST OF TABLES

Table 1. Examples of Science and 4-H Reflection Prompts……………………………25

Table 1. Continued……….…………………………………………………………..26

Table 1. Continued….………………………………………………………………..27

LIST OF FIGURES

Figure 1. 5E Instructional Model……………………………………………..………..6

Figure 2. 4-H Experiential Learning Model………………………………………..……..8

Figure 3. Overlapping the 5E and Experiential Model……………………………………10

Figure 4. 5EIM/ELM Program Design Checklist…………………………………………13

Figure 5. Program Design Checklist……………………………………………………..…22

Figure 6. Iterative and abductive approach for identifying expression of personal significance……………………………………………………………………39

INTRODUCTION

This thesis consists of two manuscripts, a practitioner piece (Brodek & Klein, submitted), submitted to Afterschool Matters Journal, and an empirical piece (Brodek & Hufnagel, in progress), to be submitted to Environmental Education Journal. The Brodek and Klein (submitted) piece introduces a new design process for informal education programs that combines evidence-based STEM practices and experiential learning best practices. The design process was created over a two-year period, while developing a 4-H Science Toolkit for grades 3-5, about sustainable fishing and environmental DNA (eDNA). In order to produce engaging STEM lessons that were inquiry-based and student-centered, the 5E Instructional Model (Bybee, 2019) was used as a template for all lessons. The 5E Model is an effective tool for introducing science phenomena and promoting conceptual understanding (Bybee, 2019; Liu et al., 2009), however the model does not fulfill the expectations and missions that are fundamental to 4-H. The 4-H adaptation of the Experiential Learning Model supports experience-driven learning, followed by reflection and discussion (Kolb, 1984). Due to the prioritization of reflection and discussion in the Experiential Learning Model, it is better adapted to incorporate 21st century skills, such as collaboration, communication, and global awareness, as well as socio-emotional learning opportunities. In the past, the adapted 4-H Experiential Learning Model has been used for informal learning science experiences, however, because it is not designed explicitly for STEM fields, it does an adequate job of teaching science concepts. On the other hand, only using the 5E Instructional Model in informal settings can bypass necessary opportunities for including 21st century skills and aspects of Positive Youth Development. In the paper, we introduce an overlapping model that incorporates both models, highlighting phases of each model that compliment, as well as supplement each other. We also provide a program checklist that aligns with the overlapping model, for more efficient and effective program development, and a pool of science and 4-H reflection prompts.

During the developmental phase of the sustainable fishing 4-H Science Toolkit, it was tested on several groups of youth in both formal and informal learning settings, one of which was the research setting for the empirical paper (Brodek & Hufnagel, in progress) – a virtual after-school club. The after-school club was composed of four youth participants and two graduate student volunteers, including myself. As described above, the club curriculum was intentionally designed to promote reflection, connections to 21st century life skills, and spaces for youth to relate the concepts, tools, and practices of sustainable fishing to personal experiences. In order to capture the ways in which youth were experiencing the toolkit activities and overall curriculum in a deep, personal way, I had to determine what to orient to. Other scholars have studied expressions of deep, personal experiences through affect, emotions (Hufnagel, 2015), taste (Anderhag et al., 2015), and aesthetics (Wickman, 2017). However, I wanted to highlight the experiences youth shared in the discourse of the after-school club where they included themselves in moments that held significance, and how those personal, meaningful experiences allowed them to connect with science. Although personal significant moments overlapped with emotions, taste, and aesthetics at times, they did not always. Hence, I introduce the construct of personal significance to articulate the ways in which the youth expressed deep connections.

The empirical paper (Brodek & Hufnagel, In progress) highlights the ways in which youth expressed personally significant experiences and how those experiences allowed them to connect with specific aspects of the sustainable fishing curriculum, such as using microscopes, designing solutions to reduce bycatch, and various fishing methods. In order to do this, we took a discursive socio-linguistics approach (Gee, 2010; Hufnagel and Kelly, 2018) to first identify what counted as expressions of personal significance, and then how those expressions made salient the ways in which youth were connecting to aspects of sustainable fishing and fish conservation.

Chapter 1: BETTER TOGETHER: BRIDGING STEM AND EXPERIENTIAL LEAERNING TO IMPROVE INFORMAL EDUCATION PROGRAMS

Introduction

"[What I'm taking away from this 4-H club is] that there are loads of fish and other things that need help, and that there is so much to learn and how it connects to us humans." These words were used by a youth to describe the personal significance of their experience with the 4-H sustainable fishing program. This was a common outcome for youth who participated in this 4-H program. In this article, we introduce a new design process used to create this program. This process enabled us to merge STEM education best practices with Positive Youth Development elements.

There are many driving factors for the movement of incorporating STEM learning in out -of-school time (OST) (Lyon et al., 2012; Riedinger and Taylor, 2016), which focus on providing opportunities for youth to explore STEM topics in an engaging and meaningful way. OST programs allow youth to connect to science in ways that are not obtainable in the classroom. Therefore, OST programs are left to grapple with the question, "How do we develop effective STEM programs that also align with best practices of informal learning (Fenichel and Schweingruber, 2010) and encourage youth to make meaningful connections to the topic?" In other words, how can we do both well? From the development of 4-H STEM toolkits, a program design model and checklist were created to support practitioners who want to create programs that teach STEM effectively, while aligning with ideals of informal learning, such as aspects of positive youth development (PYD). The design model and checklist incorporate evidence-based models from both the STEM discipline and informal organizations, rather than designing a program that does one well and attempting to incorporate the aspects of the other retroactively.

Background

In order to produce high-quality STEM lessons for a 4-H curriculum about sustainable fishing, activities were developed using the 5E Instructional Model (5EIM) and the Experiential Learning Model (ELM) adapted to use in 4-H settings (Kolb, 1984). This innovative combination ensured that youth in grades 3-5 would be engaging in hands-on, inquiry-based science activities that allowed them to make real-world connections, expand on their current understanding of scientific concepts, and develop socio-emotional and 21st century skills through positive youth development (PYD). Research shows that the 5EIM is a successful tool for introducing STEM content and can improve science understanding (Bybee, 2019; Liu et al., 2009). The ELM has been shown to transform and internalize students' learning experiences, achieving a variety of learning outcomes (Chan, 2012).

The 5EIM was designed for teachers to sustainably outline and effectively teach science concepts using evidence-based practices, as well as being learner-centered and inquiry-based. As youth participate in experiences of scientific phenomena, educators guide youth through asking questions and reflection that promote conceptual understanding. The five phases that make up the model are: Engagement, Exploration, Explanation, Elaboration, and Evaluation; outlined in Figure 1. The Engagement phase allows educators to assess youth's knowledge on a topic, including their potential misconceptions, and engage them in a short experience that exposes prior knowledge, insight into a learning outcome, or curiosity about a concept. The Exploration section is when learners experience and explore STEM ideas through collecting data, analyzing data, or making observations. In the Explanation portion youth have the opportunity to explain their understanding, and educators introduce new concepts or relevant terminology, which moves youth towards a deeper understanding. The Elaboration phase allows youth to apply their new conceptual understanding through additional activities. Lastly, the Evaluation portion allows youth to access their understanding of concepts and for educators to assess youth progress (Bybee, 2015). The evaluation of youth understanding can, and should, be facilitated throughout all phases (Figure 1), creating more space for reflection, self-assessment, formative assessment, or program evaluation. Oftentimes instructional tools, such as the 5Es, are developed for classroom teachers to support them in designing lessons, but can also be useful for informal learning environments (Liu et al., 2009), and have been shown to improve informal science learning experiences (Chen et al., 2017). The key component of the 5EIM is that learners should experience scientific phenomena before formal instruction on that phenomena is provided.

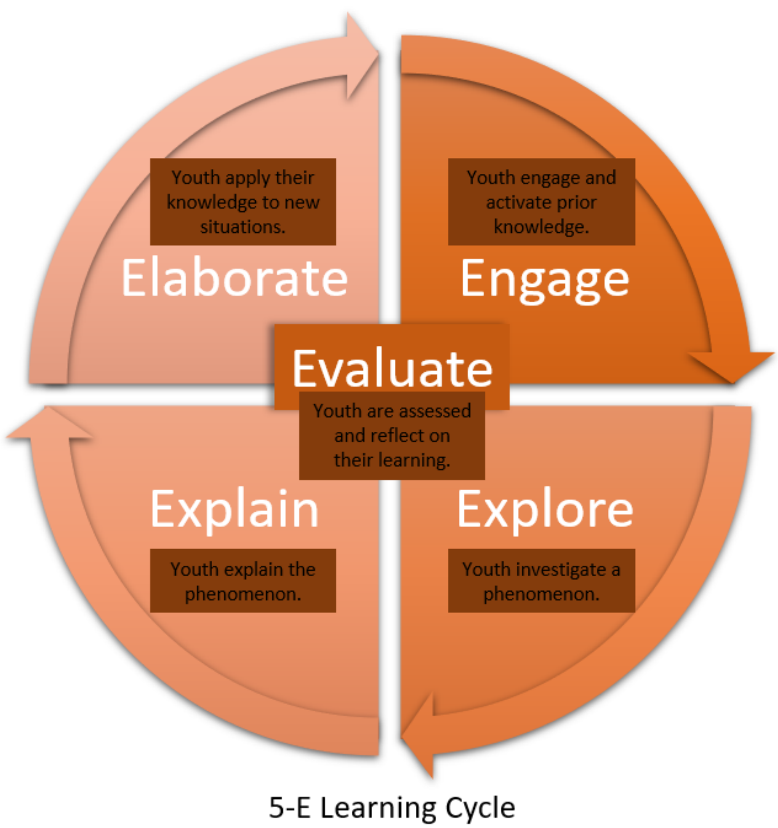
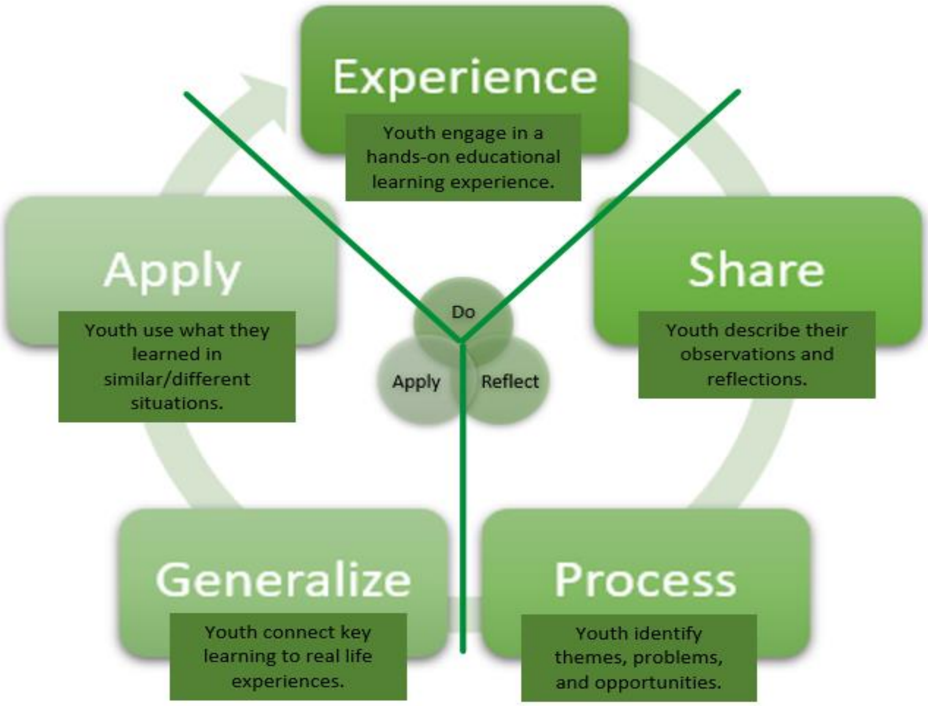


Figure 1. 5E Instructional Model

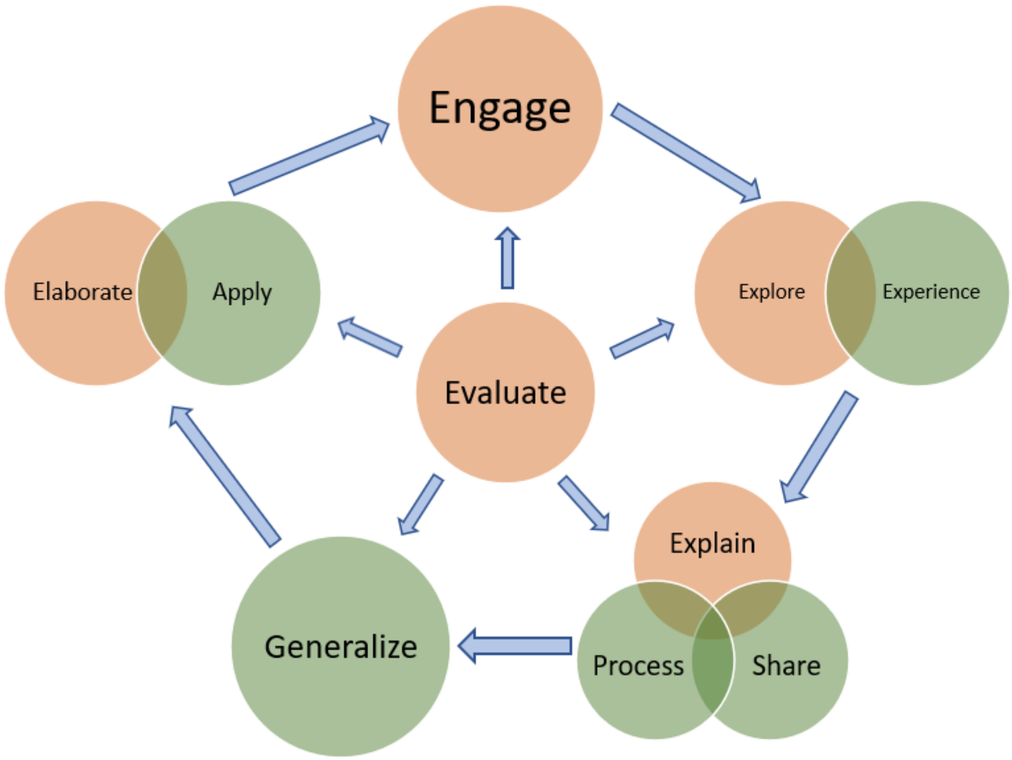
The 4-H adaptation of the ELM emerged from the foundations of the Experiential Learning Theory (Kolb, 1984), which believes that learning is driven by participating in an experience, followed by purposeful reflection and discussion. This includes articulating what happened during an activity, patterns of observation, and generalizing from those observations (Elliott-Engle, 2021). The adapted 4-H ELM is outlined in Figure 2. This model includes five steps: Experience, Share, Process, Generalize, and Apply. After youth participate in a hands-on experience, they share with others about the experience, such as what they did, what they saw, and what was difficult or easy. Then, they process the overall experience by identifying what was important and common themes, including what problems arose and how they dealt with them. The share and process phases pertain to unpacking the experience and life skills utilized during the experience. Without the inclusion of the 5EIM, the process and share phases have been the sections of the lesson where science content is explained. By separating the curriculum out into these two models, it's evident that the process and share phases are better suited as an opportunity to include life skills and socio-emotional learning. After sharing out, youth are tasked with generalizing what they learned by relating it to their lives. By reflecting on how what they did connects to their lives, they are able to apply what they learned to new or different situations (Norman and Jordan, 2006). The most important take-away from the ELM is that learners are supported in identifying, reflecting on, and developing socio-emotional and life skills.



4-H Experiential Learning Model

Oftentimes, the Experiential Learning Model that is adapted for a 4-H setting is used for STEM programs (Kolb, 1984). Because the ELM is a general model that can be used for a variety of disciplines, it has done an adequate job of teaching STEM. However, using the ELM for STEM alone can clutter the opportunities to effectively incorporate 21st century skills and PYD, as those spaces are utilized for STEM content (i.e. ELM process and share phases). The 5EIM has been shown to be more useful in teaching STEM (Bybee, 2019), but does not explicitly include room to integrate life skills and PYD that the ELM does. Using both the 5EIM and 4-H adapted ELM allows practitioners to develop high-quality STEM programs while still prioritizing opportunities for PYD.

To design a STEM curriculum using both models, we identified what phases of the models were similar and which ones supplemented aspects the other didn't address. For example, both models include a portion where youth are actively engaging in an inquiry-based experience that is youth-centered. What is not explicitly included in the 5EIM are spaces for socio-emotional skills, life skills, and moments where youth reflect on how they personally connect to or grow from the experiences; whereas, in the ELM, the process and share phases create an effective space where these skills and reflections can be integrated. Similarly, the explain phase of the 5EIM only asks youth to explain the scientific aspects of the phenomenon they just explored, whereas the ELM expands on this phase by asking youth to not only explain what they saw or did, but reflect on it (share) and process it by identifying themes, problems, and opportunities associated with life and socio-emotional skills. Combining the 5EIM and the ELM fills gaps in each model to produce youth experiences that take advantage of OST contexts. The combination of these two models supports programs that not only provide youth with high-quality science experiences that are shown to increase conceptual understanding of science content, but also provide opportunities for positive youth development, such as socio-emotional learning and development of life skills. These practices are foundational to 4-H programs, as they serve to enhance the confidence, competence, and caring character of youth (Lerner and Lerner, 2013). This overlapping model, shown in Figure 3, is flexible so that informal educators can adapt it to a myriad of contexts, in which alignments of the phases may change. Consequently, this conjoined model can be used for different types of subjects or topics.



Overlapping the **5E** and **Experiential** Models

Context

4-H is one of the largest Positive Youth Development organizations in the United States. With ties to national land-grant universities, 4-H develops engaging, youth-centered programs that provide hands-on experiences to youth in the community. The four H’s are: (1) Head: cognition and critical thinking; (2) Heart: emotional well-being and relationships; (3) Hands: social development and service to community; and (4) Health: lifestyle (Barker et al., 2010; Neff, 2013). The programs and curriculum that are developed by 4-H professionals are delivered in a variety of settings, including libraries, day camps, and clubs. One of the resources University of Maine 4-H Cooperative Extension provides to the community is 4-H STEM (science, technology, engineering, and mathematics) toolkits.

These toolkits allow youth in Maine to engage in an experiential learning opportunity about STEM. The toolkits include a collection of lessons that take between six and eight hours to complete around a scientific topic structured in the 5EIM format, as well as all the materials needed to complete them. Oftentimes they are specialized for a specific grade band (i.e. 3-5). These toolkits are designed so anyone can facilitate the activities in them, no expertise is needed. Background information on the subject and additional resources are provided and shared in the toolkits to support the facilitator. 4-H STEM Toolkits can be checked out and used by classroom teachers, librarians, parents, and volunteers.

As part of the Maine eDNA National Science Foundation (NSF) Established Program to Stimulate Competitive Research (EPSCoR) grant-funded program, we developed a 4-H STEM Toolkit about sustainable fishing and eDNA for youth in grades 3-5. The purpose of the toolkit was to (1) enhance each participant's understanding of scientific knowledge around sustainable fishing; (2) develop skills related to science such as critical thinking and reasoning with evidence; (3) develop socio-emotional and life skills, such as communication and teamwork; and (4) create a space for youth to make personal connections to science and reflect on them. The 4-H Sustainable Fishing STEM Toolkit was delivered to about 130 youth ages 8-11. Sites included classrooms, libraries, and afterschool virtual 4-H Special Interest (SPIN) Clubs. The lessons within the toolkit are described below.

Lesson Overview

In order to more easily develop programs that align with the overlapping model, we created a program design checklist that incorporates both the 5EIM and ELM (Figure 4). The checklist is a helpful resource when designing programs as it ensures the inclusion of both

STEM practices and PYD. Each stage provides an example of how the 4-H Sustainable Fishing Science Toolkit met the checklist requirements. The examples provided are described in more detail in the comprehensive lesson description below.

<table>
<tr><th colspan="2">5EIM / ELM Program Design Checklist</th></tr>
<tr><td colspan="2">Stage 1</td></tr>
<tr><td colspan="2">Engage</td></tr>
<tr><td colspan="2">Youth brainstorm Maine fish species familiar to them (Lesson 1).
☐ Create interest and stimulate curiosity
☐ Set learning within a meaningful context
☐ Raise questions for inquiry
☐ Reveal students' ideas and beliefs; compare students' ideas</td></tr>
<tr><td colspan="2">Stage 2</td></tr>
<tr><td>Explore</td><td>Experience</td></tr>
<tr><td>Species Range Map Matching (Lesson 2) – youth reason with evidence of where aquatic species in Maine would best survive based on given species parameters. Because there was more than one right answer for some species, youth took the initiative to discuss their difference in placement amongst themselves.
☐ Provide experience of a STEM phenomenon or concept.
☐ Explore and inquire into students' questions and test their ideas
☐ Investigate and/or solve problems</td><td>Science investigation (Lesson 3) – youth investigated how changing one variable impacted how water moves in a pie plate.
Scavenger hunt (Lesson 6) – youth went outside in search of evidence that animals have left behind.
☐ Provide a direct, hands-on experience that youth participate in with little or no help from the adult</td></tr>
<tr><td colspan="2">Stage 3</td></tr>
<tr><td>Explain</td><td>Share & Process</td></tr>
<tr><td>Explaining the phenomenon of sonar technology and how it works (Lesson 3) – youth are asked if they have seen fish finders in their daily lives, and if they can use that experience to explain what happened in the prior activities; connect the phenomenon to echolocation; and then explain how bouncing a rubber ball of various height objects is similar to sonar technology.
☐ Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon
☐ Construct multi-modal explanations and justify claims with evidence gathered
☐ Compare explanations generated by different students/groups
☐ Consider current scientific explanations</td><td>After engaging in activities related to bycatch (Lesson 4), youth shared they felt empathy towards animals whose habitats are being infiltrated by humans, experienced a sense of [collective] agency around needing to do something about bycatch, and described a feeling of existentialism about being only one small part of the larger collective that is a part of this crisis. This discussion developed into sharing potential design solutions that could help in reducing bycatch.
☐ Share reactions and observations with the group, such as what the most difficult part of the experience was
☐ Discuss, analyze, and reflect on the experience
☐ Discuss how themes, problems, and issues were brought out by the experience and how they can be addressed</td></tr>
<tr><td colspan="2">Stage 4</td></tr>
<tr><td colspan="2">Generalize</td></tr>
<tr><td colspan="2">"How can you use what you did here in your everyday life?" (Lesson 8) – after youth compiled and compared data, they discussed how sharing the workload of data collection made it easier for everyone, and how sharing science data about fish could help fishermen, recreational fishers, and other researchers.
☐ Support the finding of trends or common lessons that can be applied to the real world, not just the specific topic
☐ Identify real life principles that that capture the meaning of the experience, such as teamwork, perseverance, and regulating emotions.</td></tr>
<tr><td colspan="2">Stage 5</td></tr>
<tr><td>Elaborate</td><td>Apply</td></tr>
<tr><td>DNA Extraction (Lesson 7) – after youth explored how DNA is inherited, they helped extract DNA out of a strawberry to see (1) what is actually looks like and (2) that all living things contain DNA.
☐ Use and apply concepts and explanations in new contexts to test their general applicability
☐ Reconstruct and extend explanations and understandings using and integrating different modes, such as written language, diagrammatic and graphic modes, and mathematics</td><td>Considering sustainability (Lesson 5) – after youth completed the tragedy of the commons fishing activity, they discussed how considering others is a part of sustainable fishing and applied it to recreation fishing they do, eating/sharing food, and the collective good.
☐ Talk about how the new information can be applied in everyday life now or sometime in the future
☐ Apply what was learned to a new situation or practice what was learned</td></tr>
<tr><td colspan="2">Stage 6</td></tr>
<tr><td colspan="2">Evaluate</td></tr>
<tr><td colspan="2">Different perspectives (Lesson 5) – after youth defined sustainability in their own terms and were introduced to a Wabanaki perspective on sustainability, they were asked to consider how their perspective changed. They were asked about their perspective of sustainability after engaging in an activity about tragedy of the commons.
☐ Provide an opportunity for students to review and reflect on their own their own learning and new understanding and skills
☐ Provide evidence for changes to students' understanding, beliefs, and skills, etc.</td></tr>
</table>

Figure 4. 5EIM/ELM Program Design Checklist

Lesson 1: Getting to know aquatic animals

This first lesson introduced youth to what types of aquatic animals are fished for in Maine, including alewife, lobster, and cod. Youth began by recording species they already knew that were fished for in Maine (engage). After brainstorming, youth played a matching game in groups of 3 with cards that allowed them to explore various types of fish and shellfish that are fished for in Maine (explore/experience). When they got a match, they read about the species on an information sheet that described where they are found, then identified where they could be found on a map provided. During this group activity, youth were able to engage with socio-emotional skills such as assertiveness of voicing opinions and trust that all members of the group are participating to their best ability. Due to this being the first lesson in the program, this time was also used to develop group and discursive norms. After completing the activity, youth explained similarities and differences between the aquatic species and where they are found (explain/process/share). Then, youth chose one animal to draw (elaborate). A few discussion questions were asked at the end of the meeting, including "how can you use what you learned?" (evaluate/apply) and "how did you feel about this experience?" (process/share)

Image 1. Youth Drawing of Cod

Image 2. Youth Drawing of Lobster

Lesson 2: Species range

Lesson 2 challenged youth to reason with evidence as they matched aquatic fish that are fished for in Maine to a map, given the parameters that species needs to survive (explore/experience). Youth noticed that there were more potential spots on the map than species of fish, meaning that there wasn't one correct answer. This created space for youth to defend, with evidence, why they chose to put their species in a specific spot. The activity scaffolded opportunities for youth to regulate emotions if they became frustrated when they couldn't find the correct spot for a species or had different placements than others, motivating them to persist to get all six species on the map. After exploring the species ranges' for fish in Maine, youth explained how the model represent a real-world ecosystem (explain/generalize). For example, knowing the range in which specific fish species live could help fishermen know where to fish. They also reflected on what they found challenging about the activity, how they persevered through it, and how they felt about the process (share). Youth also explored virtual maps of how species distributions are shifting with warming ocean temperatures (elaborate/apply).

Lesson 3: Finding fish

Although knowing a species range is helpful to know where a species could be, how do you know when they are actually there? This is the concept youth explored in lesson 3, first by engaging in a Marco Polo type activity where they tried to point to where they thought they heard a "fish" (facilitator) swim around the room (explore/experience). Then, they watched a video about sonar technology (explain). Youth had the opportunity to investigate this phenomenon by dropping water from a pipette into a pie plate of water, where they observed how the water moved when they manipulated one variable (ex. height of dropper, volume of water in plate, or putting objects in the water) (elaborate/experience). Because youth got to choose their investigation, this provided an opportunity for them to be curious and creative. After their investigation, youth articulated the steps of their investigation and what surprised them (share). To wrap up the lesson, youth were asked "How is what we just did science?", where they made connections to the video as well as their personal experiences (evaluate/apply).

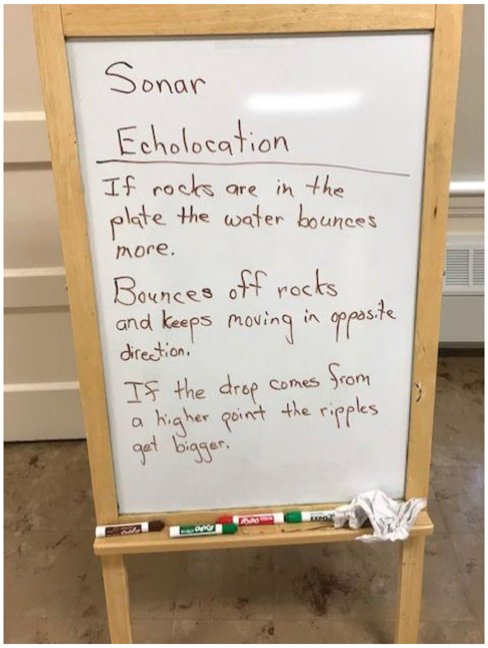


Image 3. Youth Explanation of Sonar and Echolocation

Lesson 4: Battle for fish

Similar to Battleship, in this lesson youth placed various size fish populations on coordinate grids and played against each other, trying to catch each other's populations (explore/experience). After playing, they compared where they attempted to catch fish populations to a bycatch grid, a coordinate grid with animals like whales, dolphins, and sea turtles to represent bycatch (elaborate/generalize). Youth tallied up how much bycatch they caught and reflected on how it felt to catch species by accident (share). Many of them expressed empathy towards bycatch and collective agency about needing to do something to help the animals, which led to a discussion about possible ways to reduce bycatch, including brainstorming potential designs (evaluate/process). By sharing their design ideas, they utilized several 21st century skills, such as global awareness, social responsibility, and innovation skills.

Lesson 5: Sustainable fishing

Youth began this lesson by sharing their own definition of sustainability or what sustainability means to them. Interestingly, many of them related sustainability to their energy levels and their ability to self-regulate. Then, youth were introduced to a Wabanaki perspective of sustainability, a practice called relational living (engage). The sharing of different perspectives provided an opportunity for youth to be open-minded and tolerant of others' points of view and cultures. After discussing what sustainability means, they completed a tragedy of the commons activity where they all fished out of a common bowl, trying to catch enough fish to move onto the next round (explore/experience). Inevitably, youth didn't progress many rounds before the bowl was completely devoid of fish. Youth proposed that they all needed to take out the same amount of fish, which would allow them to survive to the next round, as well as ensure that the population was large enough to reproduce an appropriate amount of future rounds (elaborate/process). This allowed them to use their communication skills to collaborate on a strategy that would be sustainable. Youth reflected on which practices were sustainable versus unsustainable (evaluate/share), what they learned about how they communicate with others (generalize), and how they can use what they learned outside of these meetings (apply).

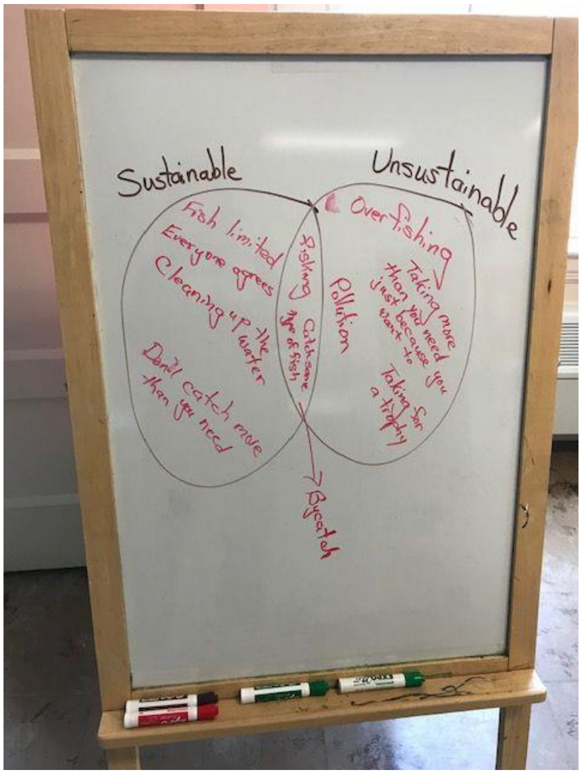


Image 4. Youth Reflection on Sustainable Practices

Lesson 6: Crime scene scientists

Lesson 6 focused on the concept that animals leave behind evidence. Youth went on a scavenger hunt outside to look for evidence that animals left behind, which communicates which animals are present in an area (explore/experience). After exploring, the group discussed how this was similar to how crime scene investigators look for evidence of humans to see who was present at a crime scene (explain/generalize). Using a soil sample taken when outside, youth placed their sample underneath a pocket microscope and observed (elaborate). Youth shared their observations and paid close attention to any evidence of animals at a smaller scale (share). Then, they discussed how the evidence left behind by animals differed as they explored macroscopic evidence in a large space compared to microscopic evidence in a small space (evaluate/share). Whether youth complete the scavenger hunt activity before the meeting or as part of it, it provides them an opportunity to meet task performance expectations, such as honoring the commitment to complete the scavenger hunt on their own, staying within boundaries when outside, and staying on task despite outside distractions.

Lesson 7: DNA

The purpose of this lesson was to provide background for the final lesson in the toolkit. In this lesson youth move colored beads through an inheritance template to model how genetic information is passed down from generation to generation, making us unique individuals (explore/experience). This is how it's possible for crime scene investigators to match human evidence, such as hair and saliva, to an individual (explain/generalize). Youth utilized critical thinking skills to interpret how the inheritance model related to their lives, making connections to the traits that were both shared and unshared in their families and using the knowledge to explain experiences in their lives. To see what DNA looks like, we extracted DNA from a strawberry (elaborate). Youth shared what they observed from the extraction and their reactions to it (share). Then, they were asked why this activity may be important to them and if it helped them understand anything about themselves (evaluate/apply).

Lesson 8: Environmental DNA (eDNA)

In this last lesson youth watched a video about how arctic charr populations in Maine are at risk due to competition and predation from rainbow smelt (engage). Youth were given the challenge to find where arctic charr, rainbow smelt, and other fish species in Maine are present through simulating the collection of eDNA in three different bodies of water: ocean, river, and pond. They collected eDNA, modeled by various colored beads, from each body of water (explore/experience). Then, they matched the color of eDNA they collected to the species with a key and recorded their findings. After they collected five samples, youth explained the steps of the procedure they went through and how it relates to what scientists do (explain/share). Then they discussed the applications of collecting eDNA to detect species presence and absence in different ecosystems compared to other ways of sampling (elaborate/generalize). In this eDNA simulation, youth had room to use critical thinking skills when analyzing and interpreting their data, collaborative skills as they worked together in groups, and social awareness as they discussed how eDNA can be used as a sustainable method to detect species' presence in water.

Discussion

A considerable amount of science learning occurs in informal and out-of-school settings throughout our lives. Informal science learning contexts provide special opportunities for science experiences that would be difficult to recreate in formal settings. These experiences that are often unique to informal spaces not only increase science content knowledge but also increase interest, motivation, enjoyment, and personal relevance of science to youths' lives (Fenichel & Schweingruber, 2010). Therefore, it is important for informal learning spaces to take advantage of this unique setting by following best practices from STEM education as well as optimizing spaces for Positive Youth Development.

Although the 5EIM has been recommended as a tool for informal education (Bybee et al., 2006), there are few examples of how to use the design model to produce quality informal lessons. There is also an absence of information on incorporating aspects of PYD, 21st century, and socio-emotional skills from the ELM within the 5EIM and vice versa. This leads us to believe that many informal contexts either develop programs that enact STEM or opportunities for PYD well, but not necessarily both. This is something we have experienced in our own 4-H context – STEM programs lacking spaces for PYD, and programs that integrate room for PYD and life skills but are not teaching STEM effectively. In fact, this is the very issue that led us to develop a new model and checklist as we created the Sustainable Fishing Toolkit. Informal education organizations that develop programs that incorporate STEM education and utilize the ELM need a tool that incorporates the best practices of each. Using the new model and checklist will enable the development of programs that effectively teach STEM disciplines while still aligning with informal best practices and the unique opportunities for PYD and life skills that accompany the ELM. The 5EIM and ELM Program Design checklist is shown in Figure 5.

Program Design Checklist	
Stage 1	
Engage	
☐ Create interest and stimulate curiosity ☐ Set learning within a meaningful context ☐ Raise questions for inquiry ☐ Reveal students' ideas and beliefs; compare students' ideas	
Stage 2	
Explore	Experience
☐ Provide experience of a STEM phenomenon or concept. ☐ Explore and inquire into students' questions and test their ideas ☐ Investigate and/or solve problems	☐ Provide a direct, hands-on experience that youth participate in with little or no help from the adult
Stage 3	
Explain	Share & Process
☐ Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon ☐ Construct multi-modal explanations and justify claims with evidence gathered ☐ Compare explanations generated by different students/groups ☐ Consider current scientific explanations	☐ Share reactions and observations with the group, such as what the most difficult part of the experience was ☐ Discuss, analyze, and reflect on the experience ☐ Discuss how themes, problems, and issues were brought out by the experience and how they can be addressed
Stage 4	
Generalize	
☐ Support the finding of trends or common lessons that can be applied to the real world, not just the specific topic ☐ Identify real life principles that that capture the meaning of the experience, such as teamwork, perseverance, and regulating emotions.	
Stage 5	
Elaborate	Apply
☐ Use and apply concepts and explanations in new contexts to test their general applicability ☐ Reconstruct and extend explanations and understandings using and integrating different modes, such as written language, diagrammatic and graphic modes, and mathematics	☐ Talk about how the new information can be applied in everyday life now or sometime in the future ☐ Apply what was learned to a new situation or practice what was learned
Stage 6	
Evaluate	
☐ Provide an opportunity for students to review and reflect on their own their own learning and new understanding and skills ☐ Provide evidence for changes to students' understanding, beliefs, and skills, etc.	

Figure 5. Program Design Checklist

Overlapping the 5EIM and ELM allowed us to create a program design checklist for informal STEM contexts that attends to all the elements that make informal contexts unique from formal contexts. One of the things that makes informal STEM learning unique is a commitment to long-term engagement, personal interests, and growth (Fenichel and Schweingruber, 2010). These commitments are highlighted in the six strands of informal science learning: (1) sparking interest and excitement; (2) understanding scientific content and knowledge; (3) engaging in scientific reasoning; (4) reflecting on science; (5) using the tools and language of science; and (6) identifying with the scientific experience (Fenichel and Schweingruber, 2010). Not only does the overlapping model include opportunities to incorporate PYD and socio-emotional skills, making the checklist specific to informal settings, but it also aligns with the best practices of informal learning listed above. For example, strand 1: sparking interest and excitement, is addressed in the engage phase; and strand 4: reflecting on science is addressed in the explain, share, and process phases.

Rather than working through one model, then trying to see where another can be incorporated, the overlapping model (Figure 3) allows you to develop a program curriculum while meeting standards of both. First, identify what the learning outcomes of the program are. What should youth be able to do at the end? Then, choose an engaging opening activity that gets youth thinking about the topic or phenomenon that is being introduced. Provide an opportunity for youth to further explore this phenomenon on their own or in groups. After they have explored on their own, prompt them to explain what they just did, what they thought or felt during the exploration, and anything they noticed or observed. As youth are explaining, this is where relevant vocabulary and terms can be introduced for youth to match STEM terminology to what they did. This is also a space where youth can process their experience – what was challenging about the activity or what problems arose, and how they worked to overcome them whether individually or as a group. There is an opportunity here to highlight relevant life skills that were or could have been utilized during the experience such as communication, empathy, tolerance, or critical thinking. The explain, share and process phase also provides an opportunity to evaluate youth. Now that youth have an understanding of a phenomenon and have shared reflections on their experience, challenge them to think about how this relates to their lives, whether they have seen the phenomenon before or how they use the aspects of socio-emotional skills or life skills that they experienced during the activity. Then, youth can elaborate on how they would apply the knowledge and skills learned to other situations or contexts, or even events where they could practice what they learned. These last two overlapping phases are also opportunities to evaluate youth on their understanding of the topic and guide them towards meeting the learning outcome. We have also provided a table (Table 1) which lists reflection prompts that can help to balance good science instruction with PYD practices and vice versa.

Table 1. Examples of Science and 4-H Reflection Questions

Phase	Science Reflection Questions	4-H Reflection Questions
5E – Engage	What are your experiences with _______? What do you know about ________? What do you not yet know about ______? What have you heard about _____ that you are not sure is true? What would you like to learn about _____? What sort of investigation would you need to do in order to find out about ______? Why do you think _____ happened?	What does ____ mean to you? After hearing a different perspective, does it change your thinking at all? After hearing a different perspective, how do you feel?
5E Explore ELM Experience	What if ____ ? Have you considered what might happen when you _____ ? Why do you suppose _____? What might you do to find the answer? Is there any information you do not yet have? Where could you find this information? What might happen if you _____ ? Why did you decide to _____ ? What patterns did you notice? What else might have caused _____? What did you expect to find and why? What do you think could be an alternative explanation? What evidence do you have about _____?	What surprised you? Was any of this new to you? What challenges did you run into? What could you do to overcome any challenges? How did you feel when you were building your design/working on this project/give specifics to project? Did you have fun? Why or why not?

Table 1. Continued

5E Explain ELM Share ELM Process	How do your observations/data support your inferences/claim/explanation? What patterns did you notice? Why do you think that___ ? What evidence do you have of this? Can you think what else might have caused it to happen? Why do you think ______? What did you expect to find? Why? Why do you think your observations were different from your expectations? How can you explain ___ ? Do you think that there might be another explanation for it? What science concepts do we know that can help us explain what happened? How could you reword your explanation to include these ___ vocabulary?	Do you have any thoughts or feelings about _____? What was going through your mind when you ____? What was hard or easy about ____? How did it feel when ___? What was it like working in a group? What was it like collaborating with others? What did ___ remind you of? Do you think someone from a different state or country would ___ the same things? How does your background influence ____? Why was this activity important to you?
ELM Generalize	Is what we just did science? How is what we just did science? How is what we did like what scientists do?	Does this remind you of anything you have experienced in your life? Describe another time you felt this way.
5E Elaborate ELM Apply	What do you already know about _____ ? How do you think this can be applied to_? What would happen if_____ ? Why do you think that_____ ? What evidence do you have of this? Can you think what else might have caused it to happen? What are the similarities between _______ and ____? Why do you think this is? What are the differences between ______ and ________? Why do you think this is? How can you explain_______ ? Do you think that there might be another explanation for it? Where can we use this concept in real life?	How can you use the ____ skill you performed here in aspects of your life? How can you use the strategies you did today in the future? What did you learn about yourself today? How can you use that in the future?

Table 1. Continued

5E Evaluate (this phase can also be used to embed program evaluation!)	How did communicating and justifying your claims to each other increase the quality of your claims (peer review)? What kind of questions can science answer? Why can only testable questions be answered with science? List four things you know about ____. Something I would like to know more about is ______. Why does _______ happen? What are the similarities between ____ and _____? Why is this? What are the differences between _______ and _______? Why is this? Explain _____ . Define____? What evidence do you have? How would you solve this ____ real-world problem? A research question is _____. What sort of experiment would you conduct in order to answer that question?	What was your goal for this activity? How did you get to your goal? Acknowledging a growth mindset, did you find anything challenging about today? How did getting through that challenge make you feel? Was there anything that sparked a new interest in you during this activity? What skills did you discover or use while working on this? What goals do you have for next year/next time based on your experience? What will you do to get there? What skills do you have that might be helpful to others? Can you think of a way to help others with those skills? Give examples.

Using this overlapping design model and checklist gives afterschool programs and practitioners an easy to use resource to effectively engage in STEM education while still making the experience unique to informal learning. The 4-H program that used these tools taught youth about science phenomena related to sustainable fishing by engaging them with student-centered activities and prompted them to reflect on how they connected to the phenomenon, life skills, and overall informal learning experience. By incorporating these resources, OST programs can continue to provide exceptional informal STEM and PYD experiences for youth.

Chapter 2: "YOU WON'T BELIEVE WHAT YOU SEE!": YOUTH EXPRESSIONS OF PERSONAL SIGNIFICANCE IN AN AFTER-SCHOOL CLUB ABOUT SUSTAINABLE FISHING

Abstract

Most informal program evaluation research focuses on how youth's knowledge, interest, motivation, or behavior change after an environmental program, but fails to capture how youth are connecting to the experience on a deep, personal level. Using an ethnographic and sociolinguistics approach, expressions of personal significance from four youth were identified and analyzed in the situated discourse of an afterschool program about fish conservation. Youth expressed personal significance about nature, family and place, and changed perspectives, which made salient how youth were relating to environmental science ideas, tools, and practices related to fish conservation on a deeply personal level. Investigating how youth are connecting personal experiences with aspects of science sheds light on ways to productively engage students in science learning contexts, as well as evaluate informal environmental programs.

Keywords: Personal significance, discourse, environmental science, fish conservation, after-school

Introduction

Informal science education is crucial in increasing the public's awareness, interest, and appreciation of science (National Research Council, 2009). It also supports STEM literacy, and encourages youth to pursue careers in STEM fields (U.S. Department of Education, 2007; National Science Board, 2007). As such, when youth participate in a long-term informal education program, youth integrate their personal experiences (National Research Council, 2009) and develop a relationship to science as early as adolescence (Tai et al., 2006; Khanaposhtani et al., 2018).

In particular, fish conservation is one area of informal science education that has recently been prioritized by the United Nations Sustainable Development Agenda 2030 (United Nations, 2015), in part due to the need for the public's involvement species conservation (Dimopoulos et al., 2008; Bright and Tarrant, 2002). While education plays a role in motivating and empowering individuals to address sustainability (Fien, 2001), a deep understanding of nature and one's relationship with it heavily impacts conservation actions (Loughland et al., 2010; Kleespies et al., 2021). Particularly for youth, a personal connection or emotional attachment is needed to protect and serve the environment, which is highly dependent on teaching methods (Tsai et al., 2021). Hence, understanding how youth make sense of species conservation in deeply personal ways is critical to considering their role in addressing related issues.

Since oceans comprise most of earth's surface, they are interconnected with climate, environment, ecology, culture, economy, and industry (Tsai et al., 2021). As aquatic and marine ecosystems change due to anthropogenic and a variety of environmental stressors (Braga et al., 2020), the impacts to species abundance, marine biodiversity, and ecosystem functioning and services are apparent (Corrales et al., 2018). Additionally, as resources for communities and local economies, fisheries also play a key socio-cultural role, preserving generational knowledge, heritage, and culture (Carvalho et al., 2021). Yet, despite the critical role fisheries have in both local and global ecosystems and economies, there is limited scholarship on youth's interactions with learning about fisheries (Clark et al., 2020). This current study serves to contribute to the limited extant research about the ways youth engage deeply with fisheries.

Species Conservation Programming For Youth

There is a dearth of studies examining youth's experiences learning about fish conservation. In preparation for this study, only three peer-reviewed papers were located on this topic. Of these studies, two empirically investigated the impacts of fish conservation programs on youth knowledge, which evaluated youth's knowledge before and after-school-based conservation education programs, and the third proposed instructional frameworks.

The empirical studies compared student knowledge before and after fish conservation learning experiences, assessing ideas such as life cycles, diet, and habitat of fish (Clark et al., 2020; Pacey and Marsh, 2013). In particular, Pacey and Marsh's (2013) goal was to improve native fish awareness with knowledge gains for children in grades K - 2 over three years. Clark et al. (2020) examined the knowledge changes of elementary, middle, and high school students in relation to their gender and ethnicity before and after a school-based program with a field trip component. Both studies observed an increase in youth's knowledge related to fish conservation (Clark et al., 2020; Pacey and Marsh, 2013). A third article suggested a set of frameworks to teach about fish conservation in ways that challenge the technocratic approach typically used in public school classrooms. Using a technocratic or engineering-style approach addresses environmental issues and climate change with industry and economics, breaking down societal problems into technical parts, often ignoring systemic inequalities and consequences (Ojha et al., 2015). In doing so, Pierce (2015) argues that the current engineering-based ways of teaching about fish conservation fail to prepare citizens effectively with the tools, knowledge, and skills to make sense of our social realities.

Knowledge about environmental issues, such as fish conservation, is not synonymous with environmental awareness, actions, or stewardship (Jensen and Schnack, 1997). In order to study how youth are connecting to informal science programs on a deep, personal level, it is necessary to examine the personally significant experiences youth invoke in the discourse of learning settings (Wickman, 2017), providing insight into how youth are relating to specific environmental science ideas, tools, and practices. As discussed below, making salient the deep ways in which youth engage with and connect to environmental science learning experiences extends beyond to personal significance. As such, we suggest that personal significance is essential to actions that benefit marine environments (Hufnagel, 2015; Tsai et al., 2021).

Conceptualization of Personal Significance

In this paper, personal significance represents a deeply personal connection to particular environmental science ideas, tools, and practices as constituted in the discourse of the science learning setting. Specifically, we bound the expressions of personal significance with the ideas, tools, and practices of sustainable fishing and species conservation, the topic of the after-school club. Expressions of personal significance reveal how youth connect to environmental science ideas, practices, and tools on a personal level, providing insight into why youth experience aspects of science as engaging or enjoyable (Anderhag, 2016). When youth experience personal significance in learning settings, they are more likely to deeply engage with environmental science, as the information is organized into existing neural connections, which impacts long-term memory storage and actively processes information (Willis, 2008).

Scholars have examined similar constructs and those inform our articulation of personal significance. In their examination of taste for science, Anderhag, Wickman, and Hamza (2015) studied the ways in which taste manifested in the discourse as a learned enjoyment of and developed familiarity with science, as well as how to be a scientist. They acknowledged the discursive manifestations of taste in moment-to-moment interactions and in patterned ways. Rather than conforming to an ideal set of habits and behaviors as a goal for connecting to science (Anderhag et al., 2015), we oriented to how youth experienced environmental science tools, practices, and ideas as deeply personal without any preconceptions about what it ought to look like. As such, expressions of personal significance makes salient the ways in which youth connect deeply with specific science components (Wickman, 2017). These deep, personal connections have been identified in previous literature with expressions of affect, such as emotions (i.e. Hufnagel, 2015), taste (Anderhag et al 2015), aesthetics, (Wickman 2017), and wonder. Emotions are mechanisms to make sense of the world, helping to organize experiences and events that reflect what one considers important and meaningful (Hufnagel, 2019a; Barret, 2017). In turn, affective expressions, especially emotions, can convey personal significance. In particular, emotions have an object (or aboutness (Hufnagel, 2015)), which is a particular idea, experience, or combination of ideas and experiences, that is the focus of an emotional experience due to their urgent and personal connection to one's goals.

For youth, personal significance can also be conveyed by invoking experiences with family and place, as well as changed perspectives. Family is a prominent influence of identity and self-concept in youth (Peterson et al., 1986; Lerner and Konowitz, 2016). Youth's social relationships with their families impact their life and future interactions, as youth acclimate into family values, perspectives, and expectations (Reyes, 2014), thus a source of personal significance. Additionally, particular places contribute to the development of one's identity and are associated with feelings of belonging (Jack, 2010). Place is a specific space that is given meaning, and can exist on a range of scales, such as places of origin (country, city, street), a school, meeting spot, or where one played with friends, and is directly associated with the memories, feelings, and meanings linked to the space (Jack, 2010). As such, youth invoking experiences with place in connection with science learning indicate personal significance.

Orienting to personal significance through discourse

As language in use (Kelly, 2007), discourse is the saying, being, and doing of interacting with the world through both verbal and nonverbal language (Gee, 2010). Discourse is constructed by people in a shared space at the same time, and as such is interactional, contextual, intertextual, and consequential (Hufnagel and Kelly, 2018). Since discourse spans space and time, it includes previous experiences, affiliations, and future goals of the individuals (Kelly, 2014). Furthermore, feelings and deeply personal connections are negotiated and constructed in the discourse in which they are built (Wickman, 2017).

Expressions of personal significance are situated in the broader discourse of the after-school club. Due to the interactional nature of discourse, expressions of personal significance both reflected and were influenced by how language was interpreted in the context of the meetings (Hufnagel and Kelly, 2018), which is why a discursive perspective was used. Contextualization cues (Gumperz, 1982) include verbal and nonverbal signs, including intonation, laughter or smiling, and gestures, which help communicate a speaker's inferences in the discourse (Gumperz, 1982; Hufnagel and Kelly, 2018). Therefore, personal significance is fluid, changing over time and through space.

Study Design

Research Setting

Expressions of personal significance were studied in the discourse of a virtual afterschool club about sustainable fishing, facilitated by two instructors affiliated with a public university in the Northeastern United States. An overall goal of the club was to support youth in exploring fish conservation by delving into various methods of identifying the presence of harvestable aquatic and marine fish. Activities to support this goal included lab-like investigations (i.e. DNA extraction), data visualization, modeling, and games. Youth discussed the sustainability of current methods to identify the presence of fish and potential solutions for protecting fisheries populations, which supported their development of environmental awareness and stewardship.

The after-school club took place over eight weeks via Zoom, meeting once a week for an hour. Before the start of the club, youth were provided materials needed to complete the activities, which were completed both individually and as a whole group. For the most part, youth left their cameras on for the entirety of the meeting. The participants were given aliases.

Participants

The after-school club was facilitated by the first author and a graduate student volunteer, Courtney. The first author was in a graduate program in science education, whereas Courtney studied genetic sequencing related to environmental issues. The first author, in consultation with university curriculum experts, developed the goals and curriculum for the club and organized the meeting times and logistics. The facilitators met once a week prior to the after-school club to review the activities and determine who would lead parts of each lesson, as they co-taught.

Youth

Each participant and their respective parent(s)/guardian(s) consented to be part of the study. All four youth participants were in grades 4-5 and with the exception of one, lived in the same town. They all were curious in nature and enjoyed exploring outside. Over the eight weeks, the youth constructed a routine where they shared significant moments of their weeks at the beginning of the meetings, including birthdays, recent adventures with family, report cards, and amounts of schoolwork. All youth actively participated in activities, sharing ideas and related experiences, often responding directly to each other without prompting from the facilitators. During individual investigations and explorations, they shared observations, inferences, and ideas with each other during the activity. During group activities, especially when taking turns, youth took on the role of facilitating, reminding each other of whose turn it was, developing strategies together, and respectfully identifying errors in each other's explanations.

Max was a talkative, enthusiastic eleven year old. He enjoyed science and technology activities, exploring with his metal detector and personal pocket microscope in his free time, with a dream of one day finding a time capsule. He was often the last one to leave the club meetings in order to suggest other related activities the group could do, such as making sustainable fishing net designs or creating their own time capsule.

Tessa was a ten year old who loved exploring on her family's farm with her sister and liked being busy with schoolwork. She was an active participant in other STEM afterschool programs, with a particular interest in computer programming and coding. She often made jokes and used friendly sarcasm with both her peers and the facilitators.

Elise was another eleven year old who enjoyed exploring outside, especially in soil. She would often be doing something with her hands during the meetings, such as stretching puddy, petting the family cat, or eating, while participating in all activities. At the beginning of the meetings, she was eager to share recent stories from traveling with a sports team, especially basketball, or what she did with her siblings that week.

Lillian was the youngest of the group. At nine years old she was more reserved than the other participants in terms of time she talked, more often communicating through facial expressions and gestures, especially when reacting to others' ideas in the meetings. Her interests included playing video games, going on walks with her family, and playing with her dog. She often talked about her future goal of being a videogame designer.

Data Sources

The first author wrote ethnographic field notes during, and memos after, each club meeting. The virtual meetings were recorded and transcribed verbatim directly from the video recordings. Transcription conventions (see Appendix) were used to capture aspects of the discourse (i.e. gestures, speech speed, outbreaths, and so forth) within the transcripts. These transcripts were then analyzed for expressions of personal significance.

Identifying What Counted As Expressions of Personal Significance

Due to the first author's role as a participant observer (Spradley, 1980), Gabby gained an understanding of what experiences or events youth considered personally significant *in situ*. For example, as each youth shared stories, experiences, and oriented to various aspects of the science ideas, practices, and tools embedded in the meetings, she had an emic perspective to learn how they expressed personal significance in the discourse (Hufnagel, 2019b).

A transcription process was utilized to capture the verbal and nonverbal text of the discourse (Ochs, 1979). Informed by Goodwin (1994), expressions of personal significance were highlighted on the transcripts while watching the video recordings of the club meetings. This process included using transcription conventions, which captured both verbal and nonverbal cues for personal significance (Gumprez, 1982). Using a dynamic abductive and iterative ethnographic approach (Agar, 2006), transcripts were revisited throughout the entirety of the iterative analysis process to refine how expressions of personal significance were constituted in the discourse.

Informed by the methodological approach to analyzing emotions of Hufnagel and Kelly (2018), expressions of personal significance were identified with the orientation to contextualization cues, linguistic features, and semantics. These features of the discourse were used in combination and not prescriptive, as the expressions of personal significance were constructed *in situ*. Contextualization cues included a range of verbal (i.e. emphasizing or repeating words) and nonverbal cues (i.e. making a circle with arms or holding up objects). Linguistic features, such as point of view (i.e. first person “I” and “we”) and amplification (“**a lo^t differently**”, “**you wouldn’t beli^eve**”, repeating “**I should’ve**”) provided insight into what youth were experiencing as personal significance (Hufnagel and Kelly, 2018). Semantics that signified judgements of experiences (Hufnagel and Kelly, 2018), in combination with the other discursive features, indicated personal significance. Examples of semantics that conveyed personal significance included affective language, such as such as “cool,” “gross,” and “love.”

Once expressions of personal significance were identified they were coded for aboutness, meaning what the expressions were "about" or the object of them. Youth experienced personal significance about how microscopes changed their view of objects of inquiry, their appreciation and fascination around nature experiences, experiences at a specific place, and experiences with family.

Expressions of personal significance were analyzed within and across the various aboutness categories (Agar, 2011). With this abductive and iterative approach (Agar, 2011), identifying the aboutness was done in concert with refining what counted as an expression of personal significance. Orienting across the categories made salient how personal significance was constituted in the discourse and how it allowed youth to connect with sustainable fishing.

Figure 6. Iterative and abductive approach for identifying expression of personal significance

Findings

Youth expressed personal significance related to the conservation of fish and other aquatic animals in the discourse of the after-school club. Youth personally connected to the use of scientific tools embedded in activities, nature experiences, and experiences with family and around place. There were also instances where the personal significance youth expressed was entangled in family, place, and nature experiences.

Experiences with Tools of Science As Personally Significant

Throughout the club meetings students expressed personal significance with tools provided by the club as well as environmental scientific tools invoked during discussions. One of the scientific tools provided to the youth for the club was a pocket microscope. Youth expressed how the tool changed their perspective of specific objects of inquiry. For instance, youth examined soil samples they collected in between meetings from their homes (inside and outside) with the pocket microscope. Doing so allowed youth to observe and notice small-scale evidence of animal presence within the soil. While youth were looking at their soil samples, they shared their observations to the whole group and in doing so expressed how their interactions with this tool were personally significant, as seen in an excerpt from Elise:

> Yeah. I me:an, **u^nder a microscope it mi^ght look gro^ss. But like, I actually li^ke dirt**....**I a^ctually, like, a^ll the time I like g^o outside I'm like**…**I'm ta^king the di^rt. And if you sla^p di^rt wid your ha:nds, it tu^rns like, not like, .hh hh we^t but like re^ally smo:oth. An like I always make like mu^d faces.** Hh ((laugh)) (meeting 6, 50:52)

For Elise, her experiences with dirt were personally significant and informed her orientation to dirt as not limited to the view provided by the microscope: that dirt looks gross. Her fond experiences with the texture and feel of dirt (**And if you sla^p di^rt wid your ha:nds, it tu^rns like, not like, .hh hh we^t but like re^ally smo:oth.**) were brought to the fore along with her enjoyment through play ("always" making mud faces). As such, her views and experiences of dirt were personally significant as the group discussed how the soil looked under the microscope.

Similar to Elise, Tessa also expressed fascination about the power of a microscope to change one's perspective. In doing so, she compared the naked eye view (without a microscope) to a microscopic view with a microscope when she shared,

> …**when you're lo^oking at no^n >microsco^pic things,< you can just se^e it with your o^wn eyes. .hh But with microsco^pic things, you se^e things a lo^t differently**, tha^n when you d^o when you're lo^okin:g a^t it ju^st from non >microsco^pic view,< **but the^n when you look at it >from microscopic view,< .hh e^verything ((moves hands together up above head and then stretches them open as they fall down to her sides)) changes.** (meeting 6, 43:29)

Tessa expressed personal significance about how "e^verything changes" when she looks at something through a microscope, amplifying the extent of the change with her hand gestures. Tessa focused on the "microscopic view" as she explained how her perspective changes, that she "see[s] things a lot differently" by examining something with a microscope. Yet when she talked about the "non-microscopic view" she did not express fascination or strong affect.

Lillian also drew from previous experiences with a microscope in her expression of personal significance. During the meeting, Lillian talked over Max to share an observation she made about soil in the fibers of the plain white paper her soil sample was on (lines 3-5).

1. Max: ...it sti^cks on the e^nd of your mi^croscope,
2. and wi^nd- pho^ne=
3. Lillian: =I can see the

4. pi^gment, on the pa^per through the- um.

5. I can see the pi^gment on the pa^per of the spo^ts where the di^rt is.

6. Max: re^ally?

7. Lillian: I-

8. yeah, a^ctually ((eyebrows raised)) e^arlier today,

9. I was lo^oking at so:me,

10. I was workin- lo^oking at like bla^ck ma^rker,

11. tha:t a^ctually that you guys had dra^wn in,

12. and there's like pink and yellow, in i(h)t.

13. It lo^oked pre^tty co(h)ol.

Lillian's interruption of Max was marked in that Lillian was a more reserved youth and in interrupting Max conveys a strong interest in the observation she made about the soil. She referenced looking at the tip of a black dry erase marker earlier that day under a microscope, in which she saw pink and yellow pigments (lines 8-13). Her raised eyebrows (line 8) and emphasis of the different colored inks (line 12) and the word "pretty" followed by "cool" with a laugh, all worked in conjunction to relay a sense of personal significance. For Lillian, personal significance was constituted as she experienced seeing something differently (soil particles in the fiber of the paper, black ink consisting of yellow and pink inks) through the use of the microscope.

Not all the expressions of personal significance were related to the microscopes provided by the club. Max, for instance, shared a personally significant experience looking at soil using his own pocket microscope:

... **>I remember a< ti^me when I went do^wn to look in dirt with my- thi^s microscope.** ((holds up his own microscope))**...And I we^nt do^wn very de^ep, until the di^rt got red. Like it- I went tha^t deep. (+) Like with a sho^vel. Like a hu^ge ###, >and I went a^t< it for like an ho^ur >when I finally got to< r^ed di^rt. (+) I to^ok it, and >I lo^oked at it under the microscope.< You won't beli^eve >what you see.**< (meeting 6, 41:37)

Similar to his peers' experiences, Max's use of his own pocket microscope outside of the after-school club allowed for a different perspective of soil. In recounting the experience, Max expressed intense fascination about examining red dirt under the microscope (**You won't beli^eve >what you see**<), amplified by his idiom (**You won't beli^eve**) suggesting surprise of what one would see. His triumphant experience of reaching the depth of the red dirt (**>and I went a^t< it for like an ho^ur >when I finally got to< r^ed di^rt.**) and looking at it under the microscope relayed personal significance.

Nature as Personally Significant

In this paper we define nature as both the physical features of it and how it can be studied. Youth experienced personal significance about appreciating nature, including animals and plants, and the fascinating ways it can be studied.

For instance, Elise expressed personal significance about her experiences with worms, and particularly with their trails, which informed how she connected to the lesson about identifying animals and their presence through the evidence species leave behind. When Elise shared images of the evidence of animal presence she found during her scavenger hunt, she was asked if she wanted to explain anything about them, to which she responded:

> U:m, I ki^nd:a just, (+) >I don't know,< oI found them [evidence of animal presence]o. **I sho^uld've to^ok pictures of**, …we g:o an we fi^nd stuff in the ya^rd. And **I, always look for wo^rm:s and there's like all these wo^rm trails, ((smiles)) sho^uld've took a picture of it.** (meeting 6, 20:04)

When given the opportunity to explain her example of evidence of animal presence, Elise dampened her interest in her original examples (**U:m, I ki^nd:a just, (+) >I don't know,< oI found themo**). Rather, she orients to the personal significant experiences with worms and worm trials, as she repeats she "**sho^uld've took a picture of [them]**". Her affable experiences with worms and their trails (**I, always look for wo^rm:s and there's like all these wo^rm trails**) was compounded with her smile as she mentioned the experiences, informing how she connected to the ideas and practices of evidence of animal presence in nature.

Tessa also expressed an appreciation of nature that was imbued with personal significance related to DNA. After extracting the DNA from a strawberry as a group during a meeting, youth discussed what the DNA reminded them of. Tessa shared it reminded her of strawberries, which she loved:

> I just- u:m, **it reminded m^e of- number o^ne eating strawberries. ((laugh)) I lo^ve strawberries, so that's a:h go^od thing.** (meeting 7, 53:49)

Tessa expressed personal significance about her love of strawberries and eating them. She indicated that the experiment mainly (**number o^ne**) reminded her of "**eating strawberries**", which she loves (**I lo^ve strawberries**), adding "**that's a:h go^od thing**". Her appreciation of strawberries, a product and experience affiliated with nature, allowed her to connect to the DNA extraction experiment. In comparison, Tessa also expressed personal significance regarding her appreciation of nature when describing her empathy towards marine animals.

> …**I^'m just thinking about like in the re^al world, .hh we^'re the ones that are infiltrating their ha^bitat. Whi^ch one was there firs:t? Se^als, tu^rtles, dolphin and wha^le:s or hu^mans?** (+) **Cause we^'re the people that ar:e se^tting tra^ps that could b:e bette:r...**(meeting 4, 58:15)

Tessa expressed compassion about how humans are infiltrating marine animal habitat (**we^'re the ones that are infiltrating their ha^bitat**), made more salient by the rhetorical question she poses (**Whi^ch one was there firs:t? Se^als, tu^rtles, dolphin and wha^le:s or hu^mans?**) afterwards. These two excerpts from Tessa highlight different ways her personal significant experiences about nature were constituted in the discourse of two separate meetings, both indicative of how she connected to the ideas, practices, and tools of sustainable fishing.

Unlike his peers, Max oriented to nature more holistically while referencing soil. Max expressed fascination about how scientists have the ability to take a closer look at something, like soil, to learn more about it.

...And the^y can find out a li^st of e^very si^ngle thing insi^de of it. Square i^nch by square i^nch. And tha^t's something that- ob^viously, like the famous sci^entists oha:ve, and they have like,o and they kno^w how to d^o that and stuff. (meeting 6, 57:57)

For Max, his affective expressions related to what scientists can infer from nature make salient the personal significance about how one can study nature. His fascination with the great detail in which an object, in this case, soil, can be studied (...**a li^st of e^very si^ngle thing insi^de of it. Square i^nch by square i^nch.**). His emphasis of each word relayed awe at the extent to which life and particles exist within soil.

Place Experiences as Personally Significant

In this paper, place refers to a specific area youth had a personal connection to. In the first excerpt below, place represents the area around Max's house, somewhere he explored often and was familiar with. In the second excerpt, place represents a specific area that is common to watch the spawning migration of alewife.

Max expressed personal significance about observing a nest close to his house change over time, when sharing what he found during an evidence of animals scavenger hunt.

A:nd (+) this. It's a li^ttle suspi^cious. But right around he^re, ((moves cursor in a circle around dark mass wedged between tree branches high up in a tree)) **it lo^oks, ki:nd of like, so^mething was >li^ving there.< It was the^re la^st summer, and it looked a lot ne^ater, so I think it's a^ctually been wo^rn do^wn, by sto^rms and**

stuff. I thi^nk the birds le^ft wherever they we^re up here. (+) Bu^t so^mething seems to b^e there. (meeting 6, 18:02)

As Max described his photo of a nest in a tree, it's apparent that he was noticing this nest for some time, indicated by his reference to it being there "**la^st summer**" when it looked "**a lot ne^ater**" as if "**so^mething was >li^ving there.<**". He inferred that the nest might have been "**wo^rn do^wn, by sto^rms and stuff**", perhaps influenced by the changes he saw due to the proximity of the nest to his home, or from his own experience of the weather in the area. Max's experiences noticing the nest change were personally significant, influencing the inclusion of this example for the scavenger hunt and his connection to the activity.

In meeting 1 youth explored various harvestable species including cod, haddock and alewife. Max knew what alewives were because he had a personal significant experience with them at a well-known local migration site, highlighted here:

S:o I went <to this pla^ce> that's really clo^se near us. And >it was the< al^ewives. They were ju^mping up the stre:am. ((smiles)) And I ac^tually caught a couple with my ba^re ha^nds. It was pre^tty co^ol. (meeting 1, 33:35)

Max brought to the foreground his extraordinary experience of seeing alewives "**ju^mping up the stre:am**", where he "**ac^tually caught a couple with [his] ba^re ha^nds.**" His fondness of the experience was made salient by contextualization cues (smile) and semantics (**It was pre^tty co^ol.**). The personal significance experiences of seeing alewives migrate upstream and trying to catch them created an opportunity for Max to connect to this activity and the after-school cub overall.

Entanglement Across Place-Family and Nature Experiences

Expressions of personal significance were embodied across experiences with nature, family, place, and scientific tools. However, youth also expressed a deep personal connection about more than one idea or experience at a time, meaning experiences with place, family and nature were entangled. For instance, Tessa shared this experience fishing at her grandparent's home:

> **I ha:ve um. >Fished at< .hh >[name of local] pond< cuz tha^t's where my gra^ndparents currently li^ve**. But u:m we si^t on the do^ck with .hh **we all- we had like- ((talking through smile)) when we were you^nger,** ((hands outreached, palms facing each other, about a foot apart)) **me and Sco^ut had these little .hh like they were tha^t long. A:nd <they were> little Sp^iderman fishing po^les,** (meeting 1, 19:22)

As Tessa described her experience with fishing, she referred to the specific pond that her grandparents currently lived on (**I ha:ve um. >Fished at< .hh >[name of local pond]< cuz tha^t's where my gra^ndparents currently li^ve**.). As if remembering a fond memory with her sister, Scout, she smiled when describing how they used to use small Spiderman fishing poles (**when we were you^nger, me and Sco^ut had these little… Sp^iderman fishing po^les**). As Tessa shared these entangled experiences about both a specific place and family, she connected these experiences to fish conservation as personally significant.

Max also expressed personal significance about a place-family experience with nature, during a group discussion about solutions for reducing bycatch. In the excerpt below, Max oriented to how sound travels underwater based on experiences he's had with his dad in their pool.

> Ye^ah, but then sometimes that- that [acoustic] techn^ology costs lo^ts and lo^ts and lo^ts of money. **Because thi^nk about it. Yo^u kno^w, if you've ever been in a po^ol, and I've tri^ed this out with my da^d…And if you tap like a ri^ng on the side of the wa^ll, you can he^ar it very cle^arly.=Like it's ne^xt to you on the other si^de. But that on^ly la^sts for so lo^ng. Doesn't la^- even though it travels be^tter doesn't mean it trave:ls a mi^llion mi^les. Kind of- it's li:ke, after a li^ttle it gets >not as good.<=And so^metimes the techn^ology to make that sound can be ve:ry expensive. So I tho^ught, well, what if we could actually take like, everyda:y appli^ances?** (+) oWhat's somethi:ngo you >ne^ver know,< Kind of li:ke, almost li:ke whe:n we disco^vered baking soda and vi^negar had a chemical rea^ction. (meeting 4, 1:02:49)

For Max, his experiences with sound underwater at a pool with his dad were indicative of personal significance related to how he made sense of a possible solution to address bycatch. His vivid explanation of the phenomenon he witnessed, in conjunction with the emphasis placed on descriptive language (**And if you tap like a ri^ng on the side of the wa^ll, you can he^ar it very cle^arly.=Like it's ne^xt to you on the other si^de. But that on^ly la^sts for so lo^ng.**), relayed his fascination of the experience. He used this experience with his dad to inform his reasoning as to why using acoustic technology to deter bycatch wasn't the most effective, and how using "**everyda:y appli^ances**" could be cost effective.

Discussion

In this study, personal significance manifested across a range of experiences, ideas, and material objects. We found that youth connected the ideas and practices of environmental science with their own experiences and as such expressed personal significance. Extant literature found that at the primary school level, youth are interested in everyday objects (Anderhag et al., 2016; Swirski et al., 2018), such as mixing things together, conducting experiments at home, and exploring how electrical devices work, many of which were not included in their formal classroom experiences (Zimmerman and Bell, 2012). In our findings, the youth expressed personal significance while using microscopes. In doing so they evoked their previous experiences with them both in and outside of school.

Within studies on the impact of species conservation informal education programs, youth are interested in animals (Randler, Ilg, and Kern, 2005; Kleespies et al., 2021). In comparison, we found that youth personally connected to experiences in nature that often included animals, such as fishing, catching alewives with their bare hands, or worms and their trails. Ballouard et al. (2020) suggest that environmental education outside of the classroom is better suited to promote attitudes towards nature that support both the likability and protection of species. By not separating youth's personally significant experiences with nature and animals, we acknowledge the entanglement of the experiences and iterative impact on each other. Palmberg and Kuru (2010) suggested that youth's direct exposure (experiences in and with nature) can promote positive attitudes towards wildlife and nature, that in turn can lead towards a willingness to act and protect nature. In our findings, youth's affective relationships with nature manifested as wanting to create more effective fishing gear and technology.

Khanaposhtant et al. (2018) found that during an informal environmental summer camp where youth explored various soundscapes, youth related prior experiences in nature, including ones with family, with soundspaces, indicating a connection between sounds, place, family, and nature experiences. These findings align with ours, as youth shared personally significant experiences about their families in nature, in a specific place, that allowed them to connect with fish conservation and aquatic technology to reduce bycatch. Not only does this support the impact family and place have on youth, but how being in nature with family influences youth's interactions and relationships around nature. Providing relevant knowledge about environmental science ideas, tools, and practices related to significant nature experiences can strengthen their interest (Khanaposhtant et al., 2018) and value (Palmberg and Kuru, 2010) of the environment. We also found that youth expressed personal significance about experiences, such as using a microscope, that impacted their interactions with the world. Therefore, using scientific tools when discussing nature and environmental issues could shift youth's perspectives or meaning about their surroundings and interactions with it.

In this study we highlighted youth's expressions of personal significance in the discourse and how they made salient the ways in which youth personally connected with environmental science ideas, tools, and practices. However, not all personally significant expressions were included, such as emotional expressions and expressions of interest, if youth didn't provide an indication of how it allowed them to connect with aspects of environmental science. For instance, an emotional reaction to witnessing a phenomenon indicated youth experienced it as meaningful or urgent (Hufnagel, 2019a), but did not provide insight into *how* they related or connected to the phenomenon on a deeply personal level. Due to the situated nature of expressions of personal significance, it was essential to analyze expressions in the context of the discourse, but made it difficult to parse out connections to environmental science ideas, tools, or practices that were potentially out of context or not discussed in the moment. In other words, the assumption was made that expressions of personal significance were about what occurred in the moment-to-moment interactions in the after-school meetings. Due to the virtual nature of the meetings, it was challenging to clarify what youth's emotional expressions or personal significance waas about without involving the whole group.

Moving forward, it would be beneficial to conduct similar ethnographic discursive studies to identify how youth experience personal significance with other environmental science tools, concepts and practices. Due to the situated nature of personal significance, investigating how youth relate to environmental science taught with different scientific tools, interactions, discussions, and emphasis (Anderhag et al., 2015) would provide a fuller picture of expressions of youth's personal significance in a science learning context (Wickman, 2017). Taking from current research on student interest and motivation, teachers may be able to use a contextual approach, associating real-life experiences with scientific concepts, to relate to what youth find personally meaningful (Swirski et al., 2018). We propose rather than relating to just material objects youth interact with in everyday life (Swirski et al., 2018; Anderhag et al., 2016), expanding on experiences they found personally significant and why.

Conclusion

The call for research is shifting towards seeking to identify what specific environmental science ideas, practices, and tools youth are relating to that allow them to connect with environmental science on a deep, personal level (Anderhag et al., 2016; Zimmerman and Bell, 2012). Youth sharing experiences that make salient their care, admiration, and fascination of and experiences with nature are better indicators of environmental action and stewardship than knowledge, because the former includes the ways youth are deeply engaging with specific aspects of environmental science (Hufnagel, 2015). When youth relate to science on a personal level, the learning experience is organized into existing neural connections integrated both with personal experiences and environmental science ideas, tools, and practices (Willis, 2008). These long-lasting neural networks consisting of knowledge and personal experiences, support youth to be not only literate in species conservation but with a care and appreciation of nature itself. In other words, science knowledge or enjoyment no longer satisfies the evaluation of youth's literacy related to aquatic and marine ecosystems, and species conservation.

This study suggests orienting to youth's expressions of personal significance as a useful way to gain insight into how youth are engaging with environmental science tools, practices, and concepts on a deeply personal level. Overlooking how youth connect to aspects of environmental science fails to acknowledge one of the most effective evidence-based mechanisms of learning retention - youth personally relating to science (Wickman, 2017; Willis, 2008). Equipped with a personal, meaningful connection to fish conservation and related environmental issues, youth are more probable to act in ways that protect and serve the environment (Tsai et al., 2021). By supporting and validating youth's experiences with nature, and by extension science, you're also encouraging youth's ability to see themselves as scientists, as they build their understanding of science around personally significant experiences (Gonsalves et al., 2013). Furthermore, if youth are able to see how their experiences with nature, scientific tools, family, and place are directly related to environmental science and issues, they may see the benefit of being a lifelong learner.

For teachers, leveraging youth's interests, experiences, and motivations would provide framing concepts, phenomena, and tools in ways youth find personal significance. For instance, now knowing why youth relate to environmental scientific tools, such as microscopes, educators could utilize a change in perspective as a way to engage youth in a deeply, personal way in a science setting. As youth shared impactful experiences and why they were significant (it was cool, fascinating, personally meaningful), it highlighted the ways youth were connecting to specific concepts, which teachers could employ. In turn, youth would be encouraged to deeply engage with science, with a stronger promise of environmental awareness, care, and stewardship (Hufnagel, 2015). For youth, sharing personally significant experiences in the discourse of science learning settings allows them and their teachers to see how they are connecting with science ideas, tools and practices, aiding in overall metacognitive skills. Knowing which aspects of science they relate to most strengthen their long-term relationship with science and learning (Willis, 2008).

CONCLUSION

The design and implementation of the overlapping 5E Instructional Model (Bybee, 2019) and 4-H adapted Experiential Learning Model (Kolb, 1984) provided space for youth to express personally significant experiences that made salient how they were connecting to sustainable fishing ideas, tools, and practices. Together these papers highlight how informal science or environmental programs can optimize reflection, 21st century skills, and aspects of Positive Youth Development, such as a positive view of one's own actions, a positive experience with an adult and peers, and a sense of empathy towards others (Lerner and Lerner, 2013). In doing so, supports a deep, engaging connection for youth between their personally significant experiences and science.

Studying personal significant expressions is important in a science learning setting because research supports that when youth have a personal connection to ideas and practices, they are more likely to retain information and store it in their long term memory (Willis, 2008). As a result, youth are creating neutral connections between their own noteworthy experiences and science information, scaffolding metacognitive skills that will last (Willis, 2008). Not only does personal significance have the potential to increase knowledge retention, but it also creates an opportunity for youth to realize that within their personal experiences, they are doing science and being scientists. For instance, Max made connections between a personal significant experience with his dad, listening to sounds underwater and using acoustic technology to reduce bycatch in the Apply/Elaborate phase of the lesson. Max applied his personal experience to new concepts learned in the meeting, such as bycatch, and explained how he could use his experience to inform designs that could reduce bycatch. He made a connection between the observations and inferences made in his experience with the concept of bycatch, along with his appreciation and fascination with nature.

Stories and descriptions of personal experiences that may be considered irrelevant or distracting in the learning setting, are rich moments that allow one to see into (1) what youth are experiencing as personally significant, and (2) how they are using those experiences to relate to science. Orientation to personal significant expressions can provide insight into what youth find interesting, fascinating, what they appreciate and care for. For instance, microscopes personally resonated with youth, allowing them to experience a change in perspective about an object, and similar scientific tools could be incorporated in future 4-H Toolkits, followed by opportunities to reflect, share, and discuss. In addition, knowing that youth who participate in 4-H after-school clubs most likely experience nature as personally significant can provide an opportunity to incorporate ways to relate the STEM concepts to ones relevant in nature.

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APPENDIX

Transcription Conventions

(+)	short pause
(.5), (1.5)	examples of timed pauses
wo(h)rd	laugh within word
^	primary accent
[ ]	overlapping talk
.hh	in-breath
hh	out-breath
wor—	truncated word
wo:rd	stretched sound
###	unintelligible talk
=	latching (no pause between turns/words run together)
word	loud
ºwordº	quiet
>word word<	quick speech
<word word>	slow speech
((gesture))	description of gesture
?	rising intonation
,	slight rise of intonation
.	falling intonation

BIOGRAPHY OF THE AUTHOR

Gabrielle Brodek was born in Hampden, Maine and graduated from Hampden Academy. She traveled to Iowa for college, attending Drake University in Des Moines, IA, graduating with a B.S. in Environmental Science. Gabrielle has a obtained a range of positions in research, recreation, and academics, such as being a field technician in Trinidad, an educator and outreach specialist at The Ecology School in Southern Maine, substitute teacher throughout Maine, and a mentor for TRIO Upward Bound at The University of Maine. Throughout these seasonal positions, she also worked as a whitewater raft guide on the Kennebec and Penobscot rivers. Gabrielle enrolled as a graduate student in the Master of Science in Teaching program at the University of Maine in 2020. She is a candidate for the Master of Science in Teaching degree from The University of Maine in May 2022.