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Communicating Discovery Science

PRACTICE INSIGHTS

Public perceptions of ocean science as insight into discovery science

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Abstract

This article examines the complex relationship between humans and the ocean, focusing on public perceptions and the role of discovery in ocean science. For this, we use the term 'discovery' in two ways: publics 'discovering' ocean science and 'discovery' as the epistemic foundation of ocean science. Through textual analysis, we show how scientific discovery is intertwined with exploration in national-level ocean literacy policy documents. We then denote a practical and methodological distinction between discovery and basic science in ocean science. To link this back to ocean literacy, we employ Free-Choice Learning examples situated in the U.S. and Taiwan that adopt Personal Meaning Mapping to highlight how adolescents 'discover' the ocean and recognize the prevalence of discovery in ocean science. We conclude that although discovery is essential to ocean science, it is inseparable from a legacy of harm (i.e., exploitation, colonialism, and environmental degradation) which makes it — and other discovery sciences — an ongoing challenge to communicate.

Keywords

Environmental communication; Informal learning; Science centres and museums

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1 ▪ Introduction

> "*Beneath the waves, there are many dominions yet to be visited, and kingdoms to be discovered; and he who venturously brings up from the abyss enough of their inhabitants to display the physiognomy of the country, will taste that cup of delight, the sweetness of whose draught those only who have made a discovery know*" [Forbes & Godwin-Austen, 1859, p. 11].

> *"So, you know, I think the age of exploration is just beginning, not ending, on our planet. In fact, the next generation of kids… will probably explore more of Earth than all previous generations combined."* — Bob Ballard, [quoted in Conan, 2011].

> "*Oceanography, what*?" [In the Navy, 1979].

Discovery, as a concept, carries multiple interpretations within the realms of science and science communication. Traditionally, it has been seen in various lights: as the creative uncovering of nature's secrets, a view that dates back to the European Renaissance; as the product of applying creative thinking and analytical methods, as described by Kuhn [Kuhn, 1962]; and as the outcome of exploration. Further, in both traditional and contemporary accounts of science learning, discovery — especially when it stems from personal encounters with surprising or unknown phenomena — remains a vital component of learning and development. In the context of ocean science,[1] discovery is often portrayed as a journey for both professional scientists and the general public. Scientists are frequently depicted in museum exhibits, educational curricula, and media as explorers on missions to uncover previously undocumented phenomena, locations, and organisms.

Publics' responses to science are multifaceted, shaped by cultural, educational, and media influences which have a collective impact on public understanding and engagement with science [Davies, Halpern, Horst, Kirby & Lewenstein, 2019; Parsons & Carlone, 2013]. Initiatives that promote ocean literacy and public engagement, such as interactive exhibits, community science projects, and digital platforms, all play a role in fostering a more informed and supportive public, particularly in the protection and sustainable management of ocean resources. We use ocean literacy (OL) here to mean an understanding of the ocean's influence on individuals and their influence on the ocean. An ocean-literate person is someone who understands the fundamental principles and essential concepts of the ocean, can effectively communicate about it, and is equipped to make informed and responsible decisions regarding ocean resources [National Marine Educators Association National Marine Educators Association, 2021]. A key highlight of OL is the recognition that "understanding the ocean is more than a matter of curiosity" [National Marine Educators Association, 2021], but this mysterious dimension of the ocean is undeniable.

1. Ocean science is the study of the ocean and its various components. It encompasses a broad range of disciplines and focuses on understanding the physical, chemical, biological, and geological aspects of the ocean [Nature, 2024].

The unknown nature of the ocean, but proximity to humanity, primes it for discovery science. But curiosity and wonder that motivate it, can also present challenges in public comprehension and support due to differing folk epistemic notions of science — the everyday, culturally-influenced ways people understand and justify knowledge about the natural world [Sinatra & Hofer, 2016]. For example, for most of human history, the ocean was viewed as unknown and infinite, presenting challenges to explorers while offering limitless possibilities to humans [Omstedt & Gustavsson, 2022]. This perspective can sometimes make motivating ocean stewardship difficult if the ocean is perceived as an endlessly bountiful resource.

Beyond curiosity, 'exploration, experimentation, and discovery are required to better understand ocean systems and processes' [National Marine Educators Association, 2021]. However, without clear connections to immediate practical applications, some publics may perceive ocean science as distant from their everyday concerns [Naustdalslid, 2011; Norgaard, 2009; Phoenix, Boddy, Walker & Vennam, 2017]. These perceptions not only shape opinions on funding and resource allocation but also highlight a broader gap in understanding how scientific discoveries can impact societal well-being. Bridging this knowledge gap requires two-way communication that fosters dialogue between marine scientists and the public, ensuring that both sides can share perspectives and inform decision-making [Naustdalslid, 2011; Norgaard, 2009]. Rather than merely seeking public support, this approach aims to build mutual understanding, demonstrating the relevance of ocean science in addressing global challenges. Science communication strategies such as storytelling, visual media, and educational outreach are vital tools for making ocean discoveries accessible, relatable, and impactful to diverse audiences.

This article aims to highlight the important role of discovery in public understanding of oceans, and how discovery is presented in free-choice science communication and learning.[2] We begin by examining how the term 'discovery' is used in U.S. national-level education policy documents outlining OL aims in formal and free-choice learning environments (e.g., museums, aquariums, national parks, etc.). Then we provide insight into the relationship between 'discovery science' and 'basic science' in ocean science. This will be followed by an analysis of three examples from a case study in free-choice learning environments, spanning both the U.S. and Taiwan, that use multimodal communication (e.g., Personal Meaning Mapping, social media, etc.) to show how publics discover discovery in ocean science. We conclude with commentary on the state of ocean science and challenges to its legacy and ask what this means for communicating discovery sciences broadly.

2 ▪ Discovery ocean science: fulfilling curiosity and advancing ocean literacy

The communication of discovery science, and ocean science in particular, in popular media may be considered in some sense vernacular accounts of scientific points of view [Bodnar, 1994], a similar perspective on discovery in ocean science — or discovery through exploration — occurs in U.S. national-level education policy documents as well. While there are no ocean or ocean science standards in U.S. K-12 curricula, there is a widely circulated

2. Free-choice science communication refers to the exchange of scientific information in informal, self-directed learning environments, also known as free-choice learning settings, where individuals have the freedom to choose what, how, and when they engage with science content. These settings include museums, aquariums, national parks, botanical gardens, and digital platforms like social media.

and used set of documents outlining seven principles of OL [National Marine Educators Association, 2021]. Curriculum developers draw on these documents at both state and local levels as well as museum educators, curators, exhibit designers, and outreach specialists as they design communications and experiences about oceans and ocean science [National Marine Educators Association, 2021].

A content analysis of the documents that drive these curricular decisions, shaping both school-based and free-choice learning experiences, demonstrates that both discovery science and experimental science are discussed for public audiences in the context of exploration. Free-choice learning (FCL) encompasses more than interactive exhibits — it includes any unstructured, self-directed activities where individuals have control over their engagement, such as exploring beaches or rocky shorelines [Falk, Heimlich & Foutz, 2009]. Analysis using MaxQDA and focusing on occurrences of the terms discover*, explor*, and experim* was performed across Version 2 of *Ocean Literacy: The Essential Principles and Foundational Concepts of Ocean Sciences for Learners of All Ages* and the *Ocean Literacy Scope and Sequence for Grades K-12*. In these national-level framework documents, discovery is constructed as inextricably linked to the concept of exploration: 77% of the uses of “discover” or “discovery” co-occur with the terms “explore,” “explorers,” or “exploration,” which themselves occur five times more frequently alone. By contrast, the term experiment only occurs once across both documents, and within the same sentence as discovery and exploration:

> Understanding the ocean is more than a matter of curiosity. Exploration, experimentation, and discovery are required to better understand ocean systems and processes. Our very survival hinges upon it [National Marine Educators Association, 2021, p. 12].

This particular occurrence is part of a list of sub-principles contained within principle 7, the overarching idea that “The ocean is largely unexplored.”

A similar content analysis of public facing ocean policy documents, that are not explicitly educational in nature, including the National Oceanic and Atmospheric Association’s (NOAA) *National Ocean Service Strategic Plan Fiscal Year 2024–2028*, was carried out. In this case, the term *explor** only appears in the contexts of public audiences’ interactions with NOAA assets including data sets and mapping tools as well as marine sanctuaries. For NOAA’s Ocean and Atmospheric Research programs’ strategic plan [National Oceanic and Atmospheric Administration, 2020], terms related to discovery only appear twice, and in both instances co-occur with terms related to exploration, which occur six times as often. Discovery from this perspective is the outcome of exploration — a fact that is not surprising given that up to 80% of the ocean remains unexplored [National Oceanic and Atmospheric Administration, 2013; Nuñez, 2020].

The vast amount of unexplored ocean is not without exception. Polynesian sailing boats explored the South Pacific in the first millennium CE. European exploration, colonization, and exploitation from the 14th to 17th century searched for unsettled land, established economic growth, spread religion, and amassed power at a devastating cost. Then in the wake of whaling’s declinehaling towards the end of the late 19th century, oceanography emerged through the systematic collection of stories and specimens from the Challenger (1872–1876), Vega (1878–1880), and Albatross (1947 and 1948) Expeditions. These voyages turned Western naturalists into explorers and ocean discovery into a formalized science.

Discovery, encompassing both the “eureka moment” of new insights and the broader concept of successful scientific endeavors [Schickore, 2022], exposed explorers to new specimens, samples, and stories from the ocean. Extracted from their natural environments to be sold, traded, and cataloged, discoveries became the foundational data upon which ocean science was built. However, the field involves not only the identification of new species and habitats, but it also includes the elucidation of complex oceanic processes through diverse methods that build on discovery science which the policy guidelines of OL aim to capture. We see the consequences of these attempts to establish OL in educational settings across the world.

3 ▪ Building blocks for basic science: discovery science and inductive reasoning

In many places, including Taiwan, the United States, and Canada, ocean science learning in formal education settings remains limited. Schools regularly prioritize hypothesis-driven basic science, such as physics, chemistry, and integrative biology, over discovery sciences like ocean science [Freitas, Bellgrove, Venzo & Francis, 2022; Guest, Lotze & Wallace, 2015; McPherson, Wright & Tyedmers, 2020]. Basic science focuses on understanding fundamental principles and theories that describe the natural world. It aims to build a comprehensive, systematic, and universal body of knowledge that explains the underlying mechanisms governing physical, chemical, and biological processes [Feibleman, 1961]. Yet, basic science is a response to the information provided by discovery in ocean science.

Unlike most basic science research that begins with a specific question or hypothesis followed by experiments to test it, discovery-driven ocean science requires observation and data collection to uncover new insights. In other words, discovery provides the raw data and phenomena that hypothesis-driven basic science seeks to explain. However, discovery science and basic science are mutually informing; the theoretical frameworks developed by basic science can guide and inform discovery science, by for example, suggesting new areas for exploration.

Discovery science generates new knowledge through observation, exploration, and experimentation, particularly in areas with limited existing information. This approach systematically collects data to uncover patterns, relationships, and new phenomena [Anderson, 2004]. Discovery science is typically employed in fields that are not yet well understood and where hypothesis-driven research may be premature or insufficient, such as deep-sea exploration. Because discovery-driven science is unable to provide a complete account of ocean phenomena, it leads to the use of inductive reasoning [Omstedt & Gustavsson, 2022].

Inductive reasoning as a method in ocean science requires the successful observation of patterns. “Study of these patterns leads to suggestions of possible interconnections between otherwise unrelated facts, providing the stimulus for ideas about what might or might not be important in terms of causal relationships” [Anderson, 2004, p. 10]. Supported by critical and analytical methods, discovery-based observation and inductive reasoning continue to be integral to ocean science where the potential to discover novel connections is rich. Hence, ocean science offers a special lens through which to understand the relationship between basic science and discovery science, as well as insight into communicating discovery science in free-choice learning environments.

4 ▪ Discovery and discovering ocean science through free-choice learning

Discovery science allows professional scientists, budding scientists, and publics to explore the natural world. FCL settings based on discovery science are uniquely positioned to foster both enjoyment and deeper inquiry. FCL settings, such as museums, aquariums, and outdoor spaces, not only offer fun and engaging experiences but also play a vital role in sparking curiosity and encouraging a lifelong desire for science learning. Whether visitors are exploring a beach, interacting with a marine exhibit, or simply observing the environment, these activities have the potential to not only entertain but also deepen understanding.

The personal freedom to explore at one's own pace in FCL settings makes science more accessible, enjoyable, and meaningful by encouraging personal discovery and presenting phenomena 'from the field'. It fosters engagement, curiosity, and deeper understanding by allowing individuals to connect with scientific concepts in ways that align with their interests and needs [Falk, 2002, 2005; Dierking & Falk, 2016]. It presents opportunities for individuals to challenge existing ideas, connect with the known and unknown, and encourage further inquiry. Visitors may come for entertainment value but leave with a deeper appreciation and understanding of ocean science, making their learning experience more meaningful and memorable [Falk, 2002].

The Oregon Coast Quests Program, a clue-based scavenger hunt in nature, for instance, exemplifies this approach by emphasizing the importance of exploring the natural environment. It encourages individuals, particularly children, to actively engage with their surroundings. While visitors may initially be drawn in by the thrill of the hunt, they ultimately leave with a deeper understanding of ocean science and the ecosystems that shape their communities [Oregon Sea Grant, 2012].

> "Quests, set up by Oregon Sea Grant, help you to explore some of the hidden, and not-so-hidden, parts of the Oregon coast. Using clues, you can explore places like the Eureka Cemetery in Newport where one of the deceased was buried with a flag presented to her by Abraham Lincoln, likely turned to dust by now but still cool." [Ammerman, 2024].

> "The tsunami ones [quest] are also fun to create because they all have a different way of getting there, but all end at high ground... It's a great way to provide general education about what factors will create a tsunami and what to do if one is coming." — *Cait Goodwin*, [quoted in Ammerman, 2020]

FCL's flexible and immersive approach is valuable, especially when tackling complex subjects like ocean science, where knowledge gaps and uncertainties often exist. Many people engage with ocean research and discover solutions to ocean-related challenges through it

[Davies et al., 2019; Falk, 2002]. This approach offers dynamic and interactive experiences that captivate diverse audiences and inspire open-minded, lifelong learning in more effective ways than traditional classroom settings. They do this by promoting deep and sustained engagement through interactive exhibits [N. Haywood & Cairns, 2006], play — an important way children freely engage in learning during their early years [Falk & Dierking, 2002; Kola-Olusanya, 2005], creating a personal connection that enables individuals to find meaning in the information presented [Falk & Dierking, 2000; N. Haywood & Cairns, 2006], and reflection about science beyond the classroom [Reiss et al., 2016]. For example, visitors to marine animal touch tanks at aquariums often spend large amounts of time observing marine life in open-ended ways driven by their own interests and curiosity [Rowe et al., 2023].

The flexibility inherent in FCL, which is considered imperative, supports cognitive development through tactile and immersive constructivist experiences. It views knowledge not as fixed, but as constantly being constructed through an individual's encounters with the world and information about it [Falk & Dierking, 2002; Hein, 1998]. Specifically, as proposed by Dewey [1938], our knowledge and thinking develop as we encounter unexpected situations in life that provide evidence that can challenge our developing theories and schema about the world and how it works. Based on constructivist learning theories, FCL experiences present students, museum visitors, television viewers, and people experiencing natural environments with experiences, interactions, or phenomena that are surprising, awe-inspiring, and confusing. Participants are then asked to make sense of the experience by 'discovering' patterns and connections to their own knowledge or past experiences. The extent to which a learner is motivated to address the disequilibrium [Piaget, 1936] depends on more than their state of knowledge or OL. Learners bring a substantially broader array of epistemologies, many of which are not related to discovery, to make sense of the ocean and ocean science.

The value of FCL is further enhanced by its contributions to accessibility, which are especially relevant in the context of Blue Spaces — outdoor environments dominated by water such as lakes, rivers, coastal waters, canals, and ponds — which have been shown to significantly improve psychological benefits for humans, such as reducing stress and improving mental health [McDougall, Hanley, Quilliam & Oliver, 2022]. Ocean and aquatic-focused FCL settings leverage these benefits, offering personalized opportunities for learners to discover aspects of the ocean and ocean science in ways that are both educational and psychologically beneficial [Falk, 2002; Kola-Olusanya, 2005].

4.1 ▪ *From childhood wonders in aquariums to ocean advocacy*

Studies show that understanding and caring for the ocean often begins with childhood experiences of wonder and curiosity, particularly through FCL settings like aquariums [for review and discussion see Mileham, 2015; Tsai, 2024]. These early encounters allow children to connect with the vibrant marine life beneath the waves, sparking an interest in ocean ecosystems and conservation. The awe inspired by these visits often becomes a gateway to a lifelong passion for marine science, driving individuals to seek deeper knowledge and active involvement in ocean stewardship [Tsai, 2024].

As these individuals grow, many transition from passive observers into active participants in ocean conservation in a variety of ways. This may include joining environmental interest groups, pursuing hobbies related to place and environment or public participation in research through citizen science. Citizen science projects, in many ways represent the culmination of non-professional engagement with scientific research. In this sense, they are important FCL experiences for adults since learning in citizen science is typically self-directed and shaped by the participants' own experiences and motivations [Falk & Dierking, 2012; Phillips, Porticella, Constas & Bonney, 2018]. Discovery ocean science and citizen science initiatives offer hands-on opportunities to engage with real-world marine research [Earp & Liconti, 2019]. Activities such as monitoring marine species, assessing water quality, and contributing to coastal conservation efforts not only deepen scientific understanding but also foster emotional connections to marine ecosystems. These immersive experiences promote a sense of ownership and stewardship over the ocean, aligning with the broader goal of enhancing ocean literacy through active and inclusive participation [B. Haywood, Parrish, Jones & Inman, 2024]

Citizen science projects led by local communities, like Public Lab, provide a powerful example of how FCL extends lifelong learning into real-world, hands-on scientific exploration. These initiatives blend education, science, and social change, offering participants the opportunity to actively engage in environmental research driven by community concerns. In the case of Public Lab, which emerged in response to the Deepwater Horizon oil spill, local citizens took control of environmental monitoring efforts by developing and utilizing their own tools, creating a "DIY environmental science community" [Kloetzer et al., 2021].

Citizen science participants actively engage in hands-on activities, guiding their own learning experiences and are often driven by personal or local environmental concerns. This approach aligns closely with the principles of FCL, allowing individuals to pursue knowledge based on their interests in a self-directed manner. Such engagement easily connects to the concept of discovery ocean science, as participants — many of whom lack formal scientific training — immerse themselves in practical, experiential learning. Through these citizen-driven efforts, not only is scientific research enriched, but emotional and intellectual connections to the ocean are also fostered. This process cultivates a community of informed advocates for ocean literacy and stewardship.

5 ▪ Personal meaning mapping in free-choice discovery learning environments

FCL museum learning research is aided by Personal Meaning Mapping (PMM), a specially crafted lens for delving deeply into the multifaceted dimensions of visitor learning [Falk, 2003]. This allows researchers to track how an individual's knowledge, attitudes, and interests evolve as they discover ocean science content [Bailey & Falk, 2016; Falk, 2003]. Further, by allowing participants to reflect on and document their understanding over time, they participate in a reflective practice that not only deepens the learning experience but also facilitates ownership of one's learning journey, leading to more sustained interest and continued exploration of ocean science topics [Bailey & Falk, 2016; Villa, Xanthoudaki, Manzini & Lucchiari, 2018].

PMM values individual understandings and personal cognitive and socio-emotional connections to explore various ways of interacting with and extracting meaning from museum exhibits. It helps researchers gain insight into how learners from different cultural backgrounds, discover, perceive, and make sense of ocean science concepts, while simultaneously supporting visitors' own metacognition and reflection during their visit. Using thought-provoking prompts and evocative phrases, this approach acknowledges that individuals bring diverse prior knowledge and experience to every activity, creating an environment without universally 'correct' or 'incorrect' descriptions.

Learners bring with them a diverse array of epistemologies (many of which are not directly related to discovery) in order to make sense of the ocean and ocean science. Using PMM reveals how the environment, popular culture images of the ocean, and prior knowledge and life experiences influence young people's ocean-oriented Environmental Identities and Worldviews (EIW) — or how people view themselves in relation to the ocean environment[3] and the emotions they express concerning ocean-related fears and threats [Kelly et al., 2023]. These factors, along with emotions and a sense of wonder, often trigger their curiosity to explore the ocean and appreciate how much is left to discover. In what follows, we present three participant excerpts to showcase public perspectives on the ocean and ocean science through FCL with respect to how discovery is communicated.

The three examples selected come from a case study examining cultural-historical contexts and ocean-oriented EIW. The case study employed PMM to investigate how experience and folk epistemic notions of science influence early adolescents' local marine knowledge (ages 10 to 13; grades 5 through 8), which was evaluated before and after visiting a museum or aquarium (a FCL environment). The study utilized data from collaborating schools in the U.S. and Taiwan [Tsai, 2024].

Participants first completed a pre-PMM activity by drawing concepts inspired by the phrase "Ocean and me" on a sheet of paper. This was followed by a debriefing session. They then participated in hands-on activities and/or lectures led by aquarium curators.[4] Afterward, participants revised or expanded their initial drawings in the post-PMM activity, which was followed by another debriefing session.

In addition to debriefing, several participants were selected based on their PMM content to take part in in-depth interviews. These interviews provided deeper insights into how early adolescents discover, perceive, and derive meaning from ocean science through specific experiences, such as coastal trips, indigenous ceremonies, aquarium visits, and hands-on activities (e.g., beach cleanups, tsunami demonstrations, watershed games). Adolescents build their understanding of ocean science by directly engaging with the subject through hands-on activities, educational content, personal reflection, social interactions and cultural influences. This approach helps them connect new information to personal experiences, shaping their knowledge, attitudes, and behaviors related to ocean science.

6 ▪ Discovering and discovery — personal meaning mapping examples

For a clearer sense of how people participated, Figure 1 is an example of a Taiwanese student's (Participant 40) illustrated perspective on discovering more about the ocean. In their drawing, we can see their understanding of a local marine issue — marine debris.

3. 'Ocean Environment' refers to the complex and dynamic system including the ocean's physical, chemical, biological, and geological components. It also includes interactions between the ocean, atmosphere, land, and human activities.
4. These types of lectures were held in FCL settings, allowing participants to choose the order and sections they wished to attend.

During their debrief, they mentioned that the reason they drew many question marks in the ocean was because they knew that there was a significant amount about the ocean that they did not know, but some that they had only discovered through their free-choice marine course. In addition to their ignorance, they noted that there are still many additional unknowns about oceans around the world that also need to be explored. Motivated by this curiosity, they decided to join the marine club to further their understanding and contribute to exploring these global oceanic mysteries.

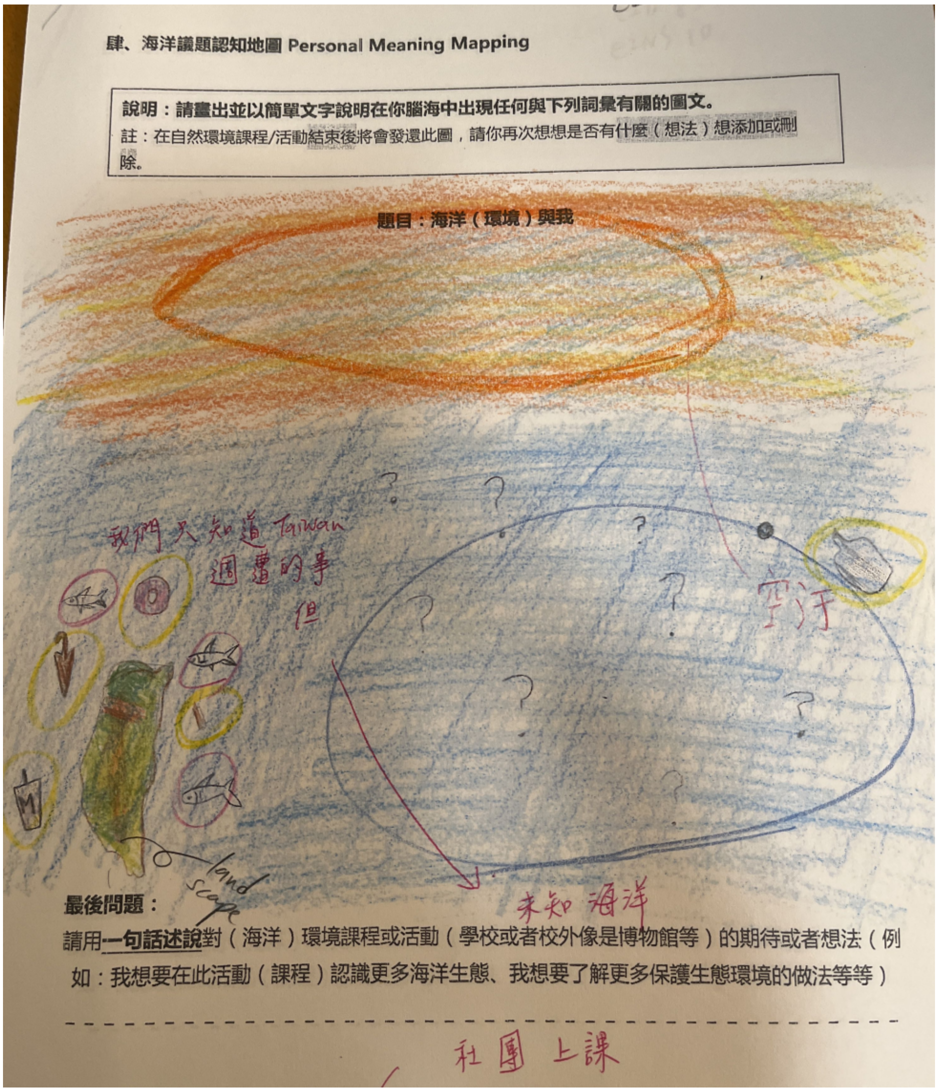

Figure 1. Pre/Post-personal meaning mapping: this picture illustrates Participant 40’s prior experiences with the marine debris issue in Taiwan and their curiosity about marine issues around the world. Sparked by their aquarium visit, additional unknowns are represented by the question marks to symbolize that they are waiting to be discovered.

This research demonstrates how individual exploration, combined with “aha” moments and natural wonder, can trigger the formation of ocean-oriented EIW. It also highlights the role of FCL in this process, such as showcasing ocean scientists’ research, which can inspire young people to discover approaches to solving ocean science-related problems.

In another example, an indigenous student (Participant 5) from Arizona drew mountains, flowers, and an imaginary ocean on the PMM before their visit to Hatfield Marine Science Center (HMSC) and added marine content after a tour at HMSC (Figure 2).

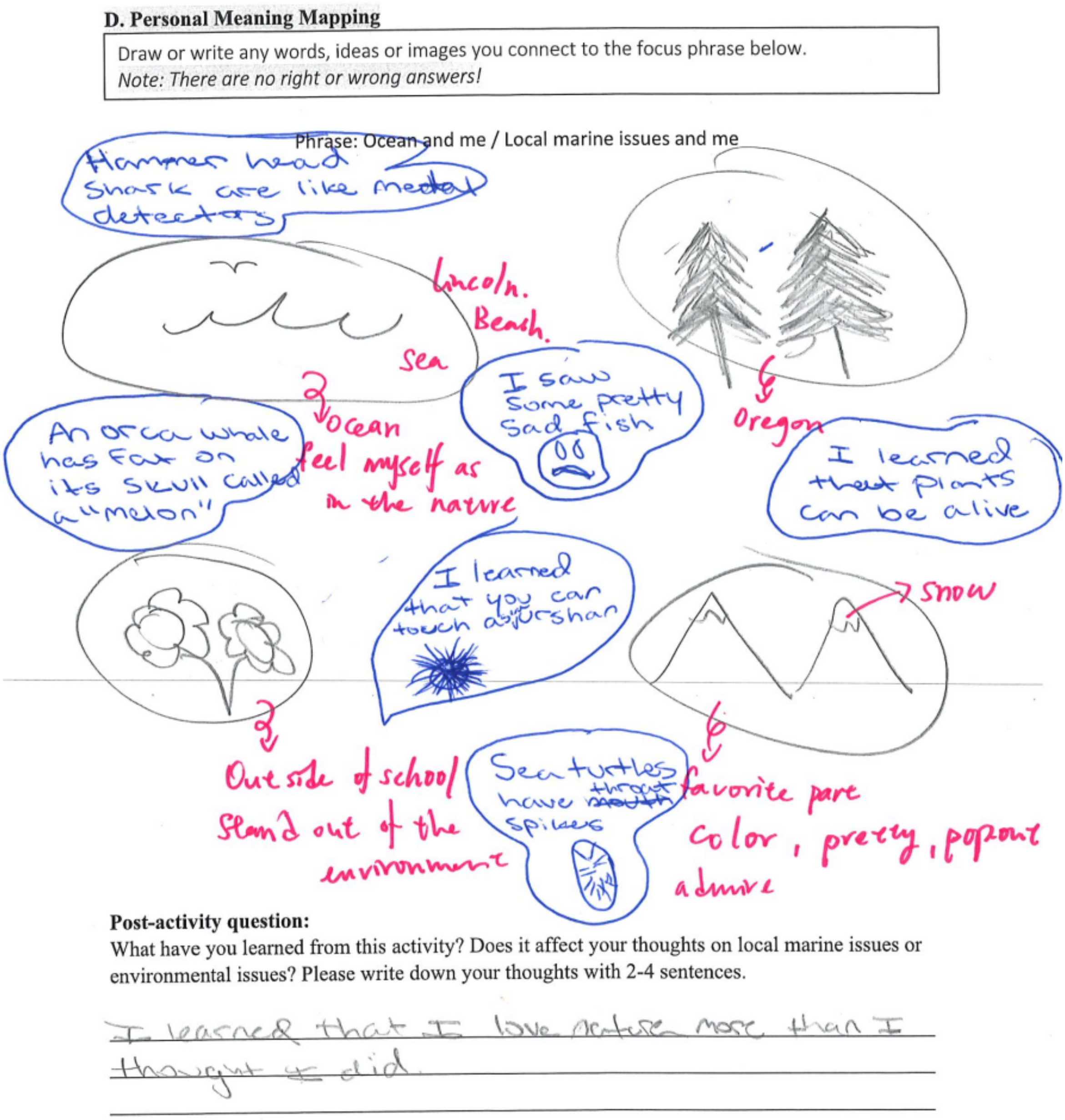

Figure 2. Pre/Post-personal meaning mapping: this picture illustrates that Participant 5 had little knowledge of ocean science before visiting the Hatfield Marine Science Center (in black pencil) but added marine content after the visit (in blue pen).

In the third example, a student from a U.S. public school (Participant 35) wrote in their PMM that “the ocean has a huge impact on me despite living the majority of my life in a landlocked state.” They mentioned being amazed by the beauty of marine species, especially orcas, which motivated them to explore more through documentaries and encyclopedias. After the BP oil spill, they vividly remembered seeing the spill on the news.

> **Participant 35:** I remember like maybe in 2013, there was a real mass like Florida Golf Coast Oil Spill [BP oil spill]. By mentioning the phrase, I remembered seeing stuff on the news about that [oil spill] a lot… It was like I was nine. I think as like an elementary school and I was like really formative because I don't know…it was crazy. I… I remember the news would be on in the morning and I would see like the pictures and stuff of it and it was really crazy. I [am] just like wow why there's all this stuff happening? And I like seeing all the oil and the animals was just like…I don't know. It was really crazy to me and like it was really sad and it was like…it stuck with me over the years, because like I, I really like to watch like documentaries and stuff and then when I saw it on the news in the morning, I was like oh my gosh…so much going on…

Their PMM (Figure 3) resembles a mind map, showing how they integrate thoughts and discoveries from various FCL sources like documentaries, museums, and news into their ocean-oriented EIW. In their PMM drawing, phrases like "Cambrian Explosion," "microplastics," and "ancient sea scorpion" reflect knowledge gained from FCL experiences. They explained how their interest in ocean-related topics grew as they connected their prior knowledge with new insights from these experiences. The BP oil spill event in particular, heightened their awareness of the uncertain state of marine welfare and sparked a desire to learn more about the ocean. This disaster not only deepened their emotional connection with the ocean but also motivated them to seek a greater understanding of the impact human activities have on marine ecosystems.

The vivid images of animals suffering from the oil spill remained with them for years, becoming a powerful motivator for their desire to explore environmentally conscious solutions. This emotional response drove them to experiment with hands-on methods, using trial and error to discover potential approaches for removing oil from affected animals and efficiently cleaning up the spill. Their response to the uncertainty and devastation of the BP spill exemplifies how personal experiences with marine crises can ignite a desire for discovery — encouraging deeper engagement with ocean science and a commitment to finding real-world solutions to pressing environmental problems.

6.1 ▪ *Summary*

FCL environments, such as museums and aquariums, play a crucial role in fostering public engagement with ocean science by offering interactive experiences that inspire curiosity and deepen appreciation for the ocean. PMM is an effective tool for capturing how individuals' perceptions and knowledge evolve before and after engaging with ocean science, making it valuable in both educational and research contexts. In these examples from the United States and Taiwan, PMM reveals the aspects of ocean science that resonate with publics and allows these learners to recall and discover ocean science in their own way, building on existing knowledge. Though our examples cannot be extrapolated to all contexts and persons, they still offer insight into how young people form their ocean identity alongside other character forming decisions.

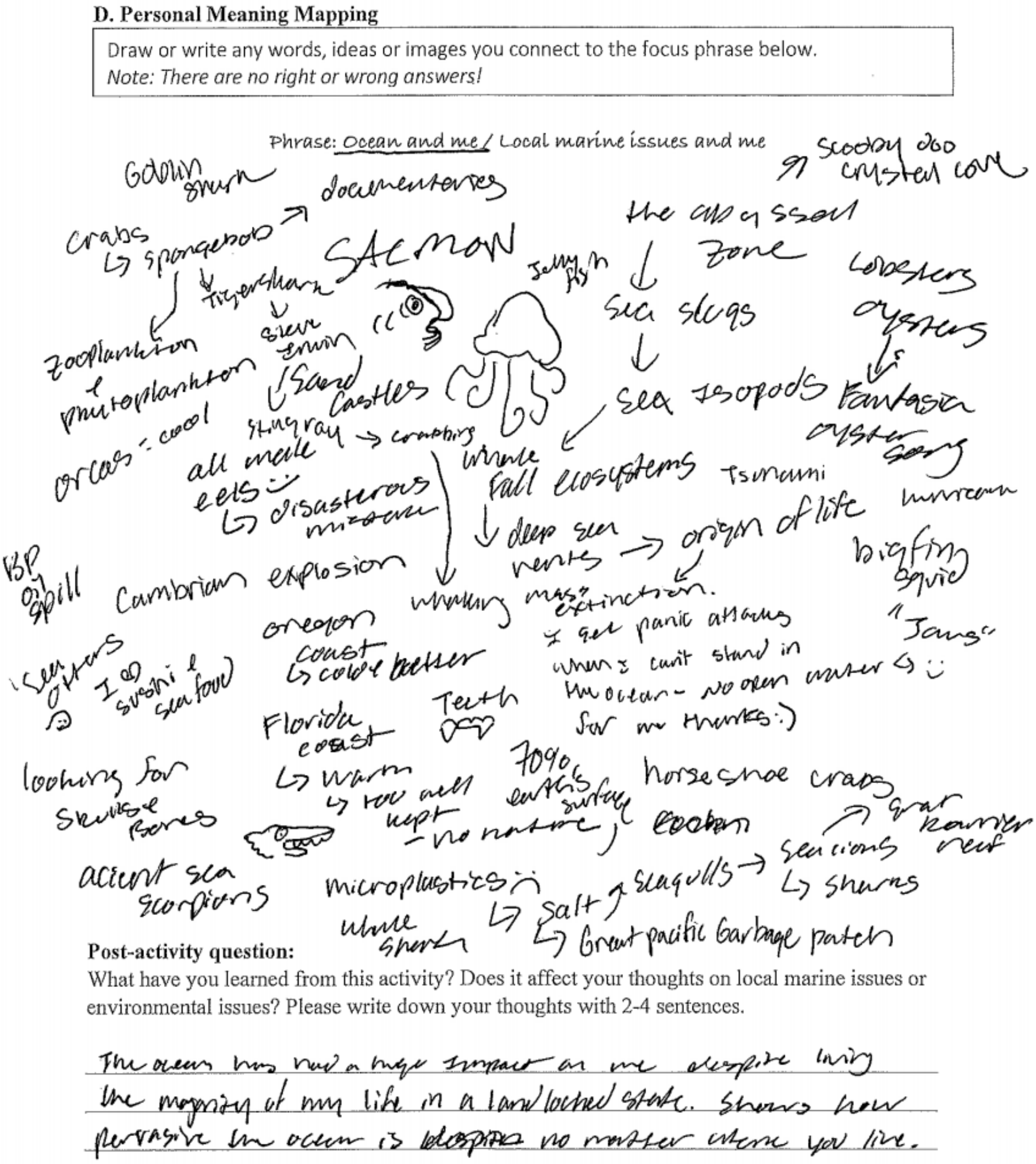

Figure 3. Pre-personal meaning mapping: this picture illustrates Participant 35's prior knowledge and experiences, triggered by the mention of the phrase "Ocean and me."

7 ▪ Legacies of discovery in ocean science and beyond

The vast and largely unexplored ocean remains a mystery to discover. As articulated by historical and contemporary figures, the quest to uncover the secrets of blue spaces is far from over. Modern technology coupled with scientific curiosity continues to drive this exploration forward [National Research Council, Division on Earth and Life Studies, Ocean Studies Board, & Committee on Exploration of the Seas, 2003] and the ongoing fascination with discovery in ocean science is mirrored in public perception and educational approaches to ocean science.

This fascination with discovery is not just about identifying new species or charting uncharted territories, but also understanding complex oceanic processes that impact Earth's climate, biodiversity, and human livelihoods. The interplay between discovery science and hypothesis-driven research underscores the dynamic nature of scientific inquiry, where observation and data collection pave the way for deeper theoretical understanding that are valuable in their own right and invaluable to understanding the world and potential futures for it.

The largely unexplored nature of the ocean and its various habitats also contribute to social constructions of ocean science that emphasize and celebrate the place of discovery as the primary role of ocean scientists. These social constructions continue to shape and be shaped by how the oceans and ocean science are described in folk notions of science and recognized by institutions.

The second decade of the twentieth century is the United Nations (UN) Decade of Ocean Science for Sustainable Development. By many accounts, attention to the ocean is long overdue. Ocean science is often overlooked compared to other discovery-oriented sciences such as astronomy and physics [Schubel, 2016; Virmani, 2017] despite it being a significant source of animal protein for more than 3 billion people [The Nature Conservancy, 2021] and playing an indispensable role in human biological and cultural evolution.

However, accounts of ocean science as discovery-based are complicit with conceptions of science and scientists as existing outside of the boundaries of everyday life because of the need for specialized knowledge, tools, equipment, or the ability to travel and collect data. The "eureka" or "aha" moment of discovery as what Kuhn [1962] called a functioning of the creative imagination — especially in the application of mathematical and logical thinking — is implicated in the romantic narrative of scientists as more than mere humans, a view that is rightfully suspect to many people today. Exploration as a concept in science is also implicated in colonialism: the search for exploitable peoples and raw materials. This view of scientists as conquerors and exploiters makes science in general (and discovery science in particular) rightfully suspect. Hence, appreciating the importance of discovery through exploration is an important element of our accounts of ocean science, but at the same time, these accounts risk exacerbating problematic values in science.

In conclusion, communicating ocean science requires more than just sharing facts about science, but rather an active examination of past discoveries, current research, and future challenges. FCL provides tools and experiences to support individuals in developing a deep, personal connection to the ocean — one that motivates them to continue exploring, learning, and advocating for marine sciences. The legacy of discovery in ocean science, therefore, is not just about what is known, but about how that knowledge is acquired, shared, and used; considerations that should apply to all discovery sciences.

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