Interdisciplinary Research through a Shared Lexicon: Merging ʻIke Kupuna and Western Science to Examine Characteristics of Water

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Traditional knowledge and Western science are two distinct disciplines that differ in methodological, substantive, epistemological, and contextual grounds. While there is increasing agreement among scholars that integrating traditional or Indigenous and Western approaches is key to solving complex environmental problems, there is also agreement that there are structural and epistemological barriers to full integration. The authors have collaborated to bridge these gaps. This article describes our attempt to integrate Indigenous knowledge and Western science through a summer research project where two of the authors, one from the biological sciences and one from political science, were asked to identify how their individual research agendas might inform the other and then identify a shared outcome that integrated both knowledge systems. Our discussions, during and after the project, revealed that the knowledge-sharing process, which resulted in the creation of a shared lexicon, was the most valuable outcome. The shared lexicon is a first step toward creating common ground between disciplines and in moving from an interdisciplinary approach toward a transdisciplinary approach to research, teaching, and learning.

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Bridging Western Science and Traditional Knowledge: Values and Limitations

The bridging of Western science and traditional knowledge to improve our understanding of ecosystems and natural phenomena is not a new concept (Kealiikanakaoleohaililani & Giardina, 2016; Mistry & Berardi, 2016; Ledward, 2013; Gagnon & Berteaux, 2009; Drew & Henne, 2006; Barnhardt & Kawagley, 2005; Agrawal, 1995). For more than fifteen years, ecological and biological sciences have acknowledged that traditional/Indigenous ecological knowledge, produced from many generations of observation of and adaptation to specific environments, is necessary for managing and sustaining the resources in particular places. However, solving emerging environmental issues, often the result of unsustainable historic and contemporary practices, requires a transformative and integrative approach to fuse multiple knowledge systems to achieve success.

Conventional hierarchical constructs of knowledge systems (Evering, 2012) can impede the ability of communities to identify and implement sustainable solutions to complex environmental issues that require transdisciplinary approaches (Mistry & Berardi, 2016; Fortuin & van Koppen, 2016; Lang et al., 2012). Evering (2012) specifically warns against a hierarchical form of knowledge integration in which Western science tends to "harvest" or "validate" Indigenous knowledge (p. 358), a practice that Mistry and Berardi (2016) similarly refer to as "a tendency among the scientific community to assimilate local ecological knowledge within Western worldviews of managing nature" (p. 1274). Lang and colleagues (2012) have argued the need for guidelines leading to a third epistemic way, which transcends approaches that favor any one epistemology in sustainability science. Indeed, case studies indicate that successful community-based conservation efforts are built upon equitable sharing and synergistic relationships between Indigenous knowledge and Western science (Shultis & Heffner, 2016; Walter & Hamilton, 2014; Shukla, 2004; Kellert, Mehta, Ebbin, & Lichtenfeld, 2000).

Traditional ecological knowledge (TEK) has been recognized as important in conservation biology (Gadgil, Berkes, & Folke, 1993; Berkes, 2004), sustainable resource use (Schmink, Redford, & Padoch, 1992), and ecosystem management (Jokiel, Rodgers, Walsh, Polhemus, & Wilhelm, 2011), to name a few. Several collaborations have been attempted by researchers to merge the knowledge domains of science with traditional customary and contemporary practices, with various degrees of success (Johannes, 1989; Simpson, 2004). The project described here is an outgrowth of attempts by the coauthors of this article to bridge the gap between Indigenous and Western knowledge systems.

From 2012 to 2014, Thomas and Aikau, along with several graduate research assistants, collaborated with Kākoʻo ʻŌiwi, a Native Hawaiian nonprofit organization working to restore wetland taro farming in the ahupuaʻa of Heʻeʻia on the island of Oʻahu, to document the impacts of restoration on water quality and the management strategies used to make decisions.[1] This project, funded by Hawaiʻi Sea Grant, was successful in many ways: We were successful at working collaboratively with the community group—the research questions were determined by the needs of the nonprofit organization, we communicated our findings back to the community group, who used the data to make informed management decisions, we trained Kākoʻo ʻŌiwi staff in water quality testing techniques, we completed an assessment of water availability for the restoration, and we provided an interdisciplinary research experience that required graduate students to translate the project's findings for

a nonexpert audience. Over the course of our collaboration, we have continued to adapt our thinking, teaching, and research practices to get closer to fully realizing our goal of doing responsive, relevant, and interdisciplinary work that takes full advantage of Western and Indigenous knowledge systems. However, we were unable to fully integrate all aspects of Indigenous knowledge and Western science in the project.

Indeed, the challenges we encountered were similar to those documented by others who have made similar efforts. The scholarly research suggests that despite attempts to bridge the epistemological gap between these knowledge systems, the Western academy appears able and willing to integrate only those aspects of TEK that are most similar to the data generated by the scientific method and that can be readily applied to those environmental problems defined by the scientific community (Simpson, 2002). What is much more difficult for the Western academy to attend to are the spiritual and ontological foundations of Indigenous knowledge systems and, as Simpson (2004) argues, the failure to account for how the impact of land and language loss due to colonization continues to impede progress. Indeed, Indigenous scholars have repeatedly noted that when Indigenous resource management strategies are effective, it is often because they were developed in conjunction with the spiritual beliefs, ceremonial cycles, place-specific practices, and worldviews that combine to inform the genealogical relationships between Indigenous peoples and their territories (Pilgrim, Samson, & Pretty, 2010; Kimmerer, 2015; Simpson, 2004; Nelson, 2008). The result is a vast imbalance and, sometimes, misrepresentations of partnerships between scientists and those who hold Indigenous knowledge (Simpson, 2001).

In an attempt to foster healthy interdisciplinary collaborations for future generations, many educators have called for the need to incorporate traditional ecological knowledge into college science courses (Bang, Medin, & Atran, 2007; Palmer, Elmore, Watson, Kloesel, & Palmer, 2009; Van Eijck & Roth, 2007; Riggs, 2005; Semken, 2005; Kimmerer, 2002; Aikenhead, 2001). Unfortunately, even with widespread acknowledgment of the complementarity between Indigenous and scientific ways of knowing, training students in multiple epistemologies to address complex issues is not a commonly adopted practice in higher education, and the general tendency is still to "enculturate all students into the value system of Western science" (Aikenhead, 2001, p. 337). This rings true based on our experiences as well. The cultural disconnect continues into postgraduate studies, where departmental stovepipes can further compartmentalize thought and critical inquiry, potentially limiting interdisciplinarity between academic units traditionally divided into sciences and liberal arts. Calls for more interdisciplinary graduate education in the sciences have been proposed, but these are often focused on integrating disciplines within a broad branch of science, such as biology (Bronson, Verderame, & Keil, 2011; Lorsch & Nichols, 2011).

Recent proposals for more transdisciplinary approaches to graduate education in conservation and environmental sciences highlight the importance of skills that will help early career scholars successfully navigate and address complex socio-ecological questions (Fortuin & van Koppen, 2016; Courter, 2012), but many graduate programs, particularly in the sciences, remain highly specialized and segregated. Unfortunately, this lack of opportunity for collaboration among early professionals of different disciplines can perpetuate misunderstanding, misappropriation, devaluation, and

marginalization of knowledge systems considered to be "other" (Simpson, 2001; 2004).

At the University of Hawai'i at Mānoa, where the coauthors have all worked, Native Hawaiian scholars have consistently argued that mo'olelo (stories/history), oli (chant), mele (song), as well as thousands of pages of nūpepa (Hawaiian newspaper) articles on topics ranging from plant names to moon phases, hold 'ike kupuna (ancestral knowledge) that is relevant to current and future researchers (Silva & Basham, 2004; Goodyear-Ka'ōpua, 2009; Wiener, 2015). However, these kinds of sources are not readily taught in college classes outside courses designated as Hawaiian or Indigenous studies. Even at a university where Hawaiian knowledge is considered to be central to its mission, 'ike kupuna continues to be relegated to those places marked as Indigenous, Native, or Hawaiian.

A pessimistic interpretation of this reality could be that this knowledge is not seen as an authoritative source equal in status to published, peer-reviewed articles. Another explanation is that because most of this archive is written in the Hawaiian language, even if these sources were seen as having value beyond providing historical baseline data, accessing this information is possible only to those scholars and researchers who have the linguistic and cultural expertise to read and accurately interpret these sources. Indeed, it is still difficult to "translate" the highly technical language of the academy into a form that is meaningful for nonexperts, and it is equally difficult to explain how mo'olelo, oli, mele, and nūpepa may hold the kinds of expert 'ike kupuna needed to solve current and future environmental crises. This being said, scholars are actively working to make this archive more accessible to the larger scholarly community. For example, Dr. Puakea Nogelmeier and the staff of Ho'olaupa'i's Hawaiian Language Newspaper Translation project, funded by a Preserve America Initiative grant from the National Oceanic and Atmospheric Administration, seek to make these invaluable resources available and accessible to the general public. Hawai'i Sea Grant developed a website (http://seagrant.soest.hawaii.edu/institute-of-hawaiian-language-research-and-translation/) that displays original Hawaiian newspaper articles along with the English language transcription.

Mālama Wai: An Exploratory Project

Over the summer of 2015, our team came together again to try to integrate science and Indigenous knowledge. The Collaborative Graduate Fellowships program, offered by the Center for Ocean Science Education Excellence Island Earth (COSEE Island Earth), was designed to foster interdisciplinary learning between graduate students of Western science and Hawaiian knowledge. A primary inspiration for COSEE Island Earth is the 'ōlelo no'eau, "'A'ohe pau ka 'ike i ka hālau ho'okahi" (All knowledge is not taught in one school). Moreover, one of the key goals of COSEE Island Earth is to bridge Western and Hawaiian knowledge and epistemologies to more holistically realize ocean literacy and conservation in Hawai'i (Lemus, Seraphin, Coopersmith, & Correa, 2014). Accordingly, as Collaborative Graduate Fellows, La Valle and Camvel were encouraged to design an interdisciplinary collaboration on some aspect of ocean-related research that integrated traditional Hawaiian knowledge and Western science. The Mālama Wai (caring for water) project set out to engage in collaborative, interdisciplinary research that could inform the research of both La Valle and Camvel, doctoral students in marine biology and political science, respectively. The

remainder of this article describes the process we undertook to create an interdisciplinary project that equally valued marine science and ʻike kupuna. We learned that before there could be any integration of knowledge systems, we first needed to create a shared language to talk about wai (water). Below is a brief overview of the common lexicon created for this project, which established common ground and goals.

The critical element of interest shared by both students was water; however, the ways in which inquiry, analysis, and hypotheses were carried out were grounded in very different approaches. Additionally, the kinds of sources and data considered to be legitimate for answering their respective research questions required different methods and objectives. When we embarked on this endeavor, the goal for this project was to integrate the practices of Western science with ʻike kupuna as part of an interdisciplinary effort to make conversant the language of science with that of Native Hawaiian moʻolelo as they relate to water.

In its most basic form, bridging science and ʻike kupuna usually follows this model: Western scientists gather Hawaiian traditional ecological knowledge and use it as a qualitative baseline or apply it to their methods, while Hawaiian cultural practitioners use modern scientific tools to help them understand their environment in contemporary times, while keeping future generations in mind. This approach might be characterized as a negotiation of knowledges within a hierarchy (Evering, 2012). Another approach is to leverage both of these different knowledge systems to help solve complex problems. These emerging issues often result from protracted contemporary practices that are unsustainable, which require transformative approaches that combine ancestral knowledge with scientific methods to achieve success. For example, the Laulima a ʻIke Pono community internship program created opportunities for community members to explore both scientific research and Indigenous moʻolelo and practices at a Hawaiian fishpond alongside scientists and Hawaiian practitioners to better understand current fishpond biogeochemistry and opportunities for restoration (Lemus, 2018).

Initially, we defaulted to the "business as usual" model and used Western scientific knowledge to authenticate place-specific, water-related moʻolelo and used traditional knowledge to inform historical land use. This work was done for three field sites on Oʻahu; however, the one site we refer to as ʻIolekaʻa is the focus of this article. ʻIolekaʻa is an undeveloped kuleana (land that was awarded to Camvel's family in the 1850s as part of the larger process of land reform called the Māhele) and is located in ʻIolekaʻa Valley, in the Heʻeʻia ahupuaʻa (watershed/land division), lying at the base of the Koʻolau Mountains, on the Windward side of Oʻahu island (see fig. 1A–B). Water quality sampling at ʻIolekaʻa was conducted on freshwater streams and on fresh water within taro fields found on the property (see fig. 1C). We were interested in comparing the site-specific moʻolelo with the "unobservable" (with the naked eye) characteristics of water such as salinity, pH, dissolved oxygen, and inorganic nutrient concentrations in areas of biological and cultural interest within the site. We also analyzed the place-based associative values pertaining to the akua (gods). Our analysis sought to locate points of overlap and synergy between the water quality data and the ʻike found in the moʻolelo.

According to a Hawaiian worldview, akua take material form (kinolau) including elements, such as rain, clouds, soil, water, and plant forms. The Hawaiian gods, in their

various capacities and forms, function as critical environmental elements whose properties are contained within the complex whole of the earth and are constituent to environmental harmony, or what the Hawaiian worldview refers to as achieving a state of pono (balance, rightness). Kūpuna constantly strived for this state of pono, and when it was maintained, the ʻāina (land, that which feeds), aliʻi nui (ruling chiefs), and the makaʻāinana (commoners) benefitted. A state of pono is not unlike sustainable, holistic approaches to resource use that meet present needs without sacrificing the needs of future generations.

ʻIolekaʻa and the Akua of Heʻeʻia

The story of ʻIolekaʻa is about ʻāina where the gods operate as elements in their micro and macro environments (Camvel, 2012). It is about the relationships between the ʻāina, humans, and the gods that surround human and nonhuman persons. The place name ʻIolekaʻa is often translated as rolling rat and, while some moʻolelo place the ʻiole (rats) who roll (kaʻa) to their deaths as central in both historical and contemporary narratives of ʻIolekaʻa, it is, by no means, the only possibility. What follows is an example of the process of Papakū Makawalu, a methodology by which Native Hawaiian words are taken apart and each component is purposefully studied in order to rethink how individual components function, to understand the relationship between their meanings and that of other terms and concepts, and to see how they fit back together, producing new knowledge or understandings. The goal is to identify deeper meanings or kaona (hidden meanings) for terms and to explore other associations with places, practices, or objects (Kanahele, 2009).

The prevailing moʻolelo of ʻIolekaʻa centers on a feud between the Heʻeʻia rats, whose feet were red, and the ʻEwa, Honolulu, and Waialua rats, whose feet were any color

Figure 1. Map of ʻIolekaʻa sampling site. (A) Map of Oʻahu. The box delineates the location of the Heʻeʻia ahupuaʻa. (B) Close-up map of the Heʻeʻia ahupuaʻa. The dashed line shows ʻIolekaʻa Valley. The dot indicates Camvel's kuleana location. (C) Conceptual map of the streams located in ʻIolekaʻa. The circles show sampling locations for water quality testing. The boxes delineate the hapahuli (taro ponds). The straight line labeled ʻauwai refers to the taro pond outflow.

but red. The malihini (stranger, outsider) rats came over the ridge and were led to their deaths by the Heʻeʻia rats, who guided them down the steep, perpendicular cliff path, leading them halfway to a moss-covered pōhaku (stone or rock), from which the malihini rats were encouraged to step and jump. Following the Heʻeʻia rats, the malihini rats, not familiar with the area, slip and fall into the pool below to their deaths (Kamakau, 1993). One interpretation of the moʻolelo is an example of how place-based knowledge, or being familiar and accustomed to the ʻāina, can be a matter of life or death. The figurative meaning for ʻiole—to steal, cheat, or lie in wait in order to assail (Pukui & Elbert, 1971)—might imply that there was something of value or significance that motivated the ʻiole malihini to traverse the ridge and be tricked into falling from such a treacherous trail. Thus, one moral of the story can be a cautionary tale about the consequences of malihini taking the resources of another ahupuaʻa. ʻIole also refers to the name of the sinker of a heʻe (octopus) lure. Given that the ʻili (land section) of ʻIolekaʻa resides within the Heʻeʻia ahupuaʻa, this could be another associative meaning for this place name.

Kaʻa means to roll, turn, twist, wallow, wind, braid, revolve; to scud or move along, as clouds; rolling, twisting, turning, sloping (Pukui & Elbert, 1971). As a noun, scud refers to Pannus clouds, grey or dark-colored clouds that look like broken layers or sheets of dark frayed clouds, which move quickly across the sky. These clouds are also called messenger clouds because when they take on a dark opaque look, they indicate that rain or snow is on its way. These clouds are common in hilly and mountainous areas and can be found all over the world (World Meteorological Organization, 2017).

When we situate these associations relative to the location of the ʻili, which is at the base of the Koʻolau Mountains on the Windward, often rainy, side of the island of Oʻahu, it is not surprising that kaʻa could also carry associations with these kinds of clouds and their movement in the sky. Additionally, within a Hawaiian worldview, the akua Lono is associated with long, dark, or black clouds, thundering and accompanying heavy rain, lightning, and rainbows of hoʻoilo (rainy season). Hoʻoilo occurs from October to January and corresponds to makahiki, a time when all people rested and abstained from work (Malo, 1987). Given how poʻe Hawaiʻi (Hawaiian people) understood these elements to be the kinolau of their beloved akua, it is likely that in giving this place the name kaʻa, kūpuna recognized the significance of rain and cloud formations in this ʻili and that these elements are sacred due to their association with the akua Lono.

In addition to the akua Lono, the akua Haumea, Hina, and Kāne are also associated with this ahupuaʻa. Haumea, a female akua (also referred to as Papa, Laka, Kapo, and Kamehaʻikana) is described by Hawaiian historian Lilikalā Kameʻeleihiwa (1999) as "most famous on the island of Oʻahu, who is the goddess of childbirth, war, and politics" (p. 4). Indeed, it is her mana wahine (female power) that she draws upon to defeat Kumuhonua, "an enemy of her kāne (male lover) Wākea" (Kameʻeleihiwa, 1999, p. 4). Portions of this moʻolelo take place in Heʻeʻia, thus grounding Haumea to various sites in the ahupuaʻa. As with many akua, Haumea can inhabit plants and is known for taking "possession of certain trees, from which are carved great war gods" (Kameʻeleihiwa, 1999, p. 5). She can also transform into moʻo wahine (female lizard deities) who serve as kiaʻi (guardians) of the wai, muliwai (brackish waters), and kai (sea waters). Hoʻomanawanui (2010) describes Haumea as the red earth mother, who births both gods and goddesses, including Hinaʻaimalama, "the goddess

of the moon, who survived domestic abuse to become a powerful goddess of healing and patroness of women's art forms, such as kapa (cloth) production" (pp. 28–29).

Hina, a female akua, is the initiator of the rhythmic cycles of the moon and is associated with growth and reproduction, and her lunar abilities promote growth through the lunar cycles and rhythmic atmospheric forces. The coral reefs are the body of Hina; coral heads (pūkoʻa) are the genitalia of Hina. From them, Hina gives birth to sea urchins, seaweeds, reef creatures, and their cousins of the land—freshwater shrimp, mosses, and small ferns (Kameʻeleihiwa, 1999), all prominent creatures in the Heʻeʻia ahupuaʻa.

The final akua associated with Heʻeʻia is the male akua, Kāne. Kāne is the primary element of fresh water and sunshine, those life-giving components that nourish the ʻāina, the kalo, and the people. This element activates photosynthesis, regulates temperature, and is a critical contributor to the growth of all living things. He is also associated with various cloud formations. As Kāneikaʻōpua, Kāne becomes the billowy white clouds on the horizon, and as Kāneikeao, Kāne becomes the floating cloud (Benson & Roseguo, 2014). Again, when we are familiar with the weather patterns in Heʻeʻia, we come to recognize these akua as ever present. We also come to understand how they work in complementary ways: Lono is the dark clouds that signal rain is approaching, while Kāneikaʻōpua reflects sunny weather. Haumea embodies the trees and plants that thrive in fresh water, while Hina embodies those creatures of the salt and brackish waters. When functioning together in a state of pono, they create an ecological environment where human and nonhuman beings can thrive. In this manner, place-based knowledge is underpinned by moʻolelo, which often reflects the symbiotic relationship between Kānaka and their environment. A closer examination of the place name, Heʻeʻia, provides an example of this. In this article we use Heʻeʻia because it reflects the geographical, topographical, and cultural significance of this particular place. The word heʻe is commonly known as octopus and also means to slide, surf, slip, or flee (Pukui, 1983). ʻIa is a particle marking passive/imperative, and eia is an idiom that means here, here is, here are, this place. As such, it is understood and known that Heʻeʻia is a place with abundant heʻe and a place that is slippery from the numerous streams and springs.

Creating a Shared Lexicon

As the project developed, some unforeseen challenges arose. Similar to the intricacies involved in translating moʻolelo, we were spending most of our time trying to explain to each other the nuances of the concepts and terms used in our different disciplines. It became clear that before we could develop an interdisciplinary approach to our study about water that combined traditional knowledge with Western approaches, we first needed to understand each other's language. From this technical difficulty in the interdisciplinary process, a new integral goal for this case study emerged:

> *Create a shared lexicon of Hawaiian language and Western science terms to help in interpreting characteristics of water, both in historical and contemporary times.*

The process of coming up with this lexicon involved several hours of talking story about our disciplines. The time committed toward this process allowed for learning about each other's values and principles, for trust to build, and for both disciplines' "voices" to be heard.

Working toward a common goal and a unified product encouraged both fields of knowledge to be involved equally and created a sense of fulfillment for all involved. This revised process addresses Simpson's (2004) critique that Western science can strip Indigenous knowledge of everything that is not valued by Western science and often does not allow for the full participation of knowledge keepers in the process of producing new knowledge.

The objective of the new research focus was to create a lexicon based on existing Hawaiian words rather than generating transliterated terms associated with water. In our unique case, a Hawaiian lexicon created with scientific terms and processes in mind could be used to understand and interpret Hawaiian moʻolelo and historical written accounts about local water bodies. Non-Hawaiian scientists and Native Hawaiian scholars who are not proficient in the Hawaiian language could also use this lexicon to understand how Hawaiian kūpuna might have understood wai.

Wai is sacred and essential to human life and to the production of kalo as a staple food of the Hawaiian people. The value of wai is evidenced by the many oli that refer to and celebrate Kāneikawaiola (the living waters of Kāne), which also refers to fresh water or springs. The lexicon we created includes the hydrological action or function, the Hawaiian concept or term, and a descriptive explanation of how that concept reflects the scientific process. The words wai honua (groundwater), kāʻamaʻai (photosynthesis), and wai kahe (flowing water) were taken from *Māmaka Kaiao*, a dictionary of Hawaiian words used to explain contemporary concepts and material culture unknown in traditional Hawaiʻi (Kōmike Huaʻōlelo, 1998). The remaining words were taken from the *Hawaiian Dictionary* (Pukui & Elbert, 1971). These two databases were the primary resources used in establishing this lexicon. Based on these dictionaries and the methodology of Papakū Makawalu, we looked for terms and concepts that reflected a Hawaiian epistemological understanding of the scientific process. In this lexicon, we sought to capture the many characteristics and nuances of wai—its flow, volume, depth, location, source, and movement—to bridge our understandings between ʻike kupuna and science (see fig. 2).

Creating a shared lexicon acknowledges the need to share a common language when tackling a common problem. It is also a tool that can be used by researchers working with Kanaka ʻŌiwi communities and by communities working with scientists. A common language is a multidisciplinary tool that can clarify the intersections, universalities, and points of incommensurability between the disciplines. Take, for example, the scientific notion of groundwater. We identified wai honua as an approximation for the meanings associated with this concept—water that resides and moves underground. Our initial search of *Māmaka Kaiao* and other Hawaiian dictionaries did not result in a Hawaiian term for this concept. While the terms wai and honua were found in Hawaiian language newspapers and moʻolelo, the two words were not used together. When combined—wai, defined as fresh water, and honua, defined as land, earth, world—they approximate the meaning and function of groundwater. Additionally, within a Hawaiian worldview, wai is figuratively associated with the circulatory system—the process of blood flowing through the human body, mostly unseen, but sustaining of life. Attention to both literal and figurative meanings of terms allows us to better understand their functions and characteristics.

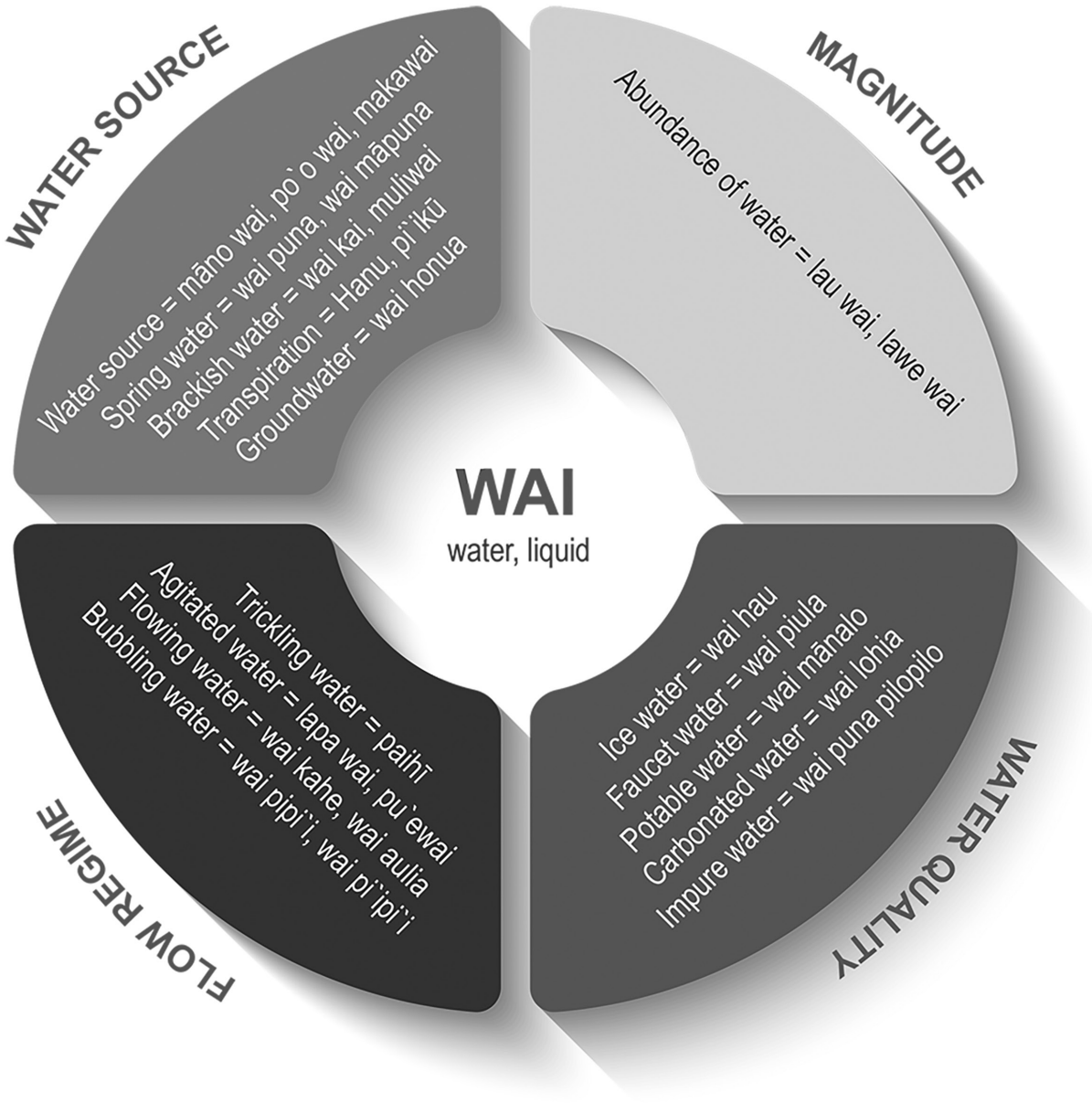


Figure 2. Graphic representation of a shared lexicon bridging Western science and traditional Hawaiian knowledge about water. The panels are divided thematically.

Shared Lexicon: A Step toward Transdisciplinarity

There are several approaches that can be used when people from multiple disciplines work together on a joint project. Figure 3 depicts three of these approaches: multidisciplinary, interdisciplinary, and transdisciplinary. This case study was initially conceived as an interdisciplinary project, where students from separate fields train each other in their discipline's discourse and integrate this knowledge in place-based research. However, as we worked on a shared lexicon, we began to develop what we consider to be transdisciplinary research.

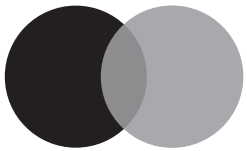
An advantage of moving toward transdisciplinary research is that it allows both parties to become unburdened by the restrictions of a single discipline and not feel like they have to defend their own frameworks. Transdisciplinary research allows for new experiences to take participants with different types of knowledge toward products that go beyond the limits of their own disciplines. In some ways, this was our experience; it was challenging to figure out what kind of product could come out of this research. In Western scientific terms, there was not enough funding to replicate the sampling process at all three sites and at the frequency needed to gather all the data and publish the results in a scientific journal. The same is true of Native Hawaiian studies, which has limited outlets for this kind of transdisciplinary research. Nonetheless, participants in this research project agreed that there was great value in the challenges we faced and in what was accomplished as we worked creatively to address these challenges.

Taking the time to think through a common problem also allows for interpersonal bonds to form and has a transformative effect on the people involved in the collaboration. In some ways, one of the most valuable outcomes of transdisciplinary research is its ability to shape and change individuals' perspectives, actions, and approaches within their own disciplines. All of the participants came away from the project with new insights that changed their behaviors. For example, Camvel, a researcher and co-owner of the ʻIolekaʻa site, learned that when water to the loʻi (taro ponds) is turned off, the pH of the soil drops very quickly, causing a possibly harmful environment for the kalo (taro). Instead, the water flow in the loʻi should be managed and regulated in more careful and cautious ways. Camvel's transformative benefit is the ongoing composition of a modern-day moʻolelo for ʻIolekaʻa that, when completed, will tell the story of this joint research effort from a Kanaka Maoli perspective. In addition, the inclusion of akua, as central to a complex ecosystem found in the Hawaiian ahupuaʻa management system, is being adopted in the creation of the moʻolelo, paying homage to the keen observation skills of the Hawaiian ancestors. La Valle learned that saying oli and pule before field work at her research sites helped to set her intentions and made her open to perceiving and appreciating the unseen elements surrounding her. La Valle also recognized that interacting with poʻe Hawaiʻi has unspoken rules that, when respected, help to build the necessary trust for collaborative work, which is not easily garnered by Western scientists.

Two undergraduate science interns were brought into the project to help with water quality sampling at ʻIolekaʻa. The interns chose to be involved in both science and community outreach work as part of their career goals. The following quotations were taken from their exit interviews.

MULTIDISCIPLINARITY draws on knowledge from different disciplines but stays within the boundaries of those fields (NSERC, 2004).

INTERDISCIPLINARITY is a synthesis of two or more disciplines, establishing a new level of discourse and integration of knowledge (Klein, 1990).



TRANSDISCIPLINARITY involves projects in which researchers from different fields not only work together closely on a common problem over an extended period, but also create a shared conceptual model of the problem that integrates and transcends each of their separate disciplinary perspectives (Rosenfield, 1992).

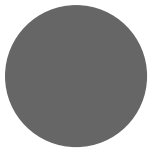


Figure 3. Definitions and graphic representation of multidisciplinarity, interdisciplinarity, and transdisciplinarity.

> *"[Camvel] not only taught me a lot about my own culture that I was very ignorant about, but how many Hawaiian stories can be shown to be accurate scientifically."*
> —Senior, Gonzaga University

> *"Working in 'Ioleka'a is what I like to call 'spiritual science.' It's much more than traditional science, there's a mystique that surrounds 'Ioleka'a. It's not just data and observation; it's something that can't be explained."*
> —Senior, University of Hawai'i at Mānoa

It is challenging to engage in interdisciplinary research between the natural and social sciences, as they draw on different conceptual frameworks with differing epistemologies. The willingness to move beyond theoretical and methodological silos and to explore other possible ways of knowing—though not our sole original intent—is evidence of the strength and uniqueness of this case study. The lexicon was a first step; we then developed a graphic representation of the lexicon that combines themes and can be used as a teaching tool in Hawaiian studies courses and in sciences classes (see fig. 2).

Conclusions and Future Directions

The call for interdisciplinary work is ever increasing at local, institutional, and federal levels (National Science Foundation, 2011). There are times when a single-discipline approach is insufficient. For example, in Hawai'i, land management is highly valued but remains a point of contention. Knowing that Hawaiian culture is built on a close-knit patchwork of communities, it is infeasible to think we can improve the health of the 'āina without several areas of expertise

working together. When embarking on an interdisciplinary project, Whitfield and Reid (2004, p. 435) suggest asking the following questions:

- Does the project require various disciplinary experts to work together (instrumental) or to create new theory or method (epistemological)?
- Are there good managers to ensure success of the process, and how?
- Is there an evaluation of success, and how?

This work requires interest on the part of funding agencies, support from institutions, and individuals who are motivated to engage in this work. One of the biggest current hurdles is that goals and products often differ for different disciplines. What is compelling to a scientific audience may not necessarily be the same for audiences interested in a Native Hawaiian perspective. More avenues, such as this journal, need to be made available for interdisciplinary research. When appropriate, these integrated products need to be implemented and institutionalized into career advancement in higher education (e.g., interdisciplinary undergraduate courses as requirements for degrees, and interdisciplinary research requirements for tenure).

Successful transdisciplinary research creates individuals who are conversant in multiple disciplines and therefore can make conceptual frameworks of several subjects more accessible for broader audiences. Even at a small scale, such as this exploratory project, it was evident that collaborating and sharing knowledge had a powerful and transformative effect on all involved.

One of the reasons this was a successful collaboration is because we were willing and excited to learn the content, values, and approaches within both fields; this type of relationship made it easier to engage in collaborative research. We also came into the project without prior assumptions about each other's disciplines and without unspoken agendas. Maintaining an open mind and showing mutual respect is especially important when dealing with two very different fields of knowledge. Throughout this inter- and transdisciplinary journey, we recognized both the values and limits of each approach and created a shared lexicon that honors Hawaiian and Western knowledge about water.

As technologies advance and global problems bring us together, the borders of disciplinary lines are getting more blurred. In general, when tackling a project or problem, we need to be better at consulting disciplines other than our own, representing all potentially useful knowledge domains and spanning all stakeholders' interests. Additionally, a transdisciplinary approach, such as the shared lexicon in this case study, may be an important way to successfully bridge Western science with ʻike kupuna while creating a useful product that all creators can take pride in.

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NOTE

1. In this paper we include contemporary spellings of Hawaiian terms using the 'okina (glottal stop) and kahakō (macron). We use Native Hawaiian, Kanaka 'Ōiwi, and Kanaka Maoli interchangeably to refer to the Indigenous peoples of Hawai'i. We also use He'e'ia as the preferred spelling for the ahupua'a (land division) on the Windward side of O'ahu, to reflect the geographical, topographical, and cultural significance of this place.