Holistic Environmental Thinking: What Western Audiences Can Learn from Indigenous Land Management

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A dissertation

submitted in partial fulfillment of the

requirements for the degree of

Doctor of Philosophy

University of Washington

2021

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Program Authorized to Offer Degree:

School of Environmental and Forest Sciences

University of Washington

Abstract

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New approaches need to be considered for environmental science education and environmental management in the United States. Current approaches to K-12 and college level STEM education tend to exclude or marginalize diverse pedagogies and epistemologies, contributing to low rates of recruitment and retention of diverse student populations in STEM fields, both at college and occupational levels. This lack of diversity has resulted in institutional dynamics and environmental land management practices that have remained largely unchanged for decades in the United States. Management models also frequently fail to appropriately engage smaller stakeholders such as Indigenous tribes and local community members that hold valuable place-based environmental knowledge. Lack of diverse perspectives and reduced information results in suboptimal outcomes, both for local stakeholders and the environment.

The goal of this research is to develop a framework for the inclusion of holistic environmental pedagogies and epistemologies in environmental science education and management, with an emphasis on partnership with Indigenous communities to achieve these goals.

Acknowledgements

I would like to take a moment to reflect on all of the people who aided me on the journey to complete this dissertation and obtain my PhD.

First, I would like to thank my dissertation committee, who provided steady guidance as I navigated the challenges of research and grad school as a single mom. Dr. Kristiina Vogt, the chair of my committee, is a patient and kind advisor who lights up the room with her sunny disposition, while keeping me on track. Committee member Dr. Daniel Vogt is one of the nicest people I have ever known, along with being a wealth of knowledge. Committee member Dr. Michael Marchand is an experienced leader who has enriched my life personally and professionally by sharing his own experiences and encouraging me to think critically. Terry Swanson, my GSR, has been invaluable in adding an outside perspective to my work.

I would like to thank Dr. Ernesto Alvarado and Dr. Tom DeLuca who first introduced me to SEFS, fire science and Indigenous land management. Thank you to SEFS staff, especially Michelle Trudeau and David Campbell who introduced me to the program and were true MVPs. Special thanks to the Confederated Tribes of the Colville Reservation and Yakama Nation. Thank you to Dr. Mike Tulee, Wendell George, Karen Matsumoto, Lacey Martin, Dr. Phil Fawcett, and others who contributed to my work and perspectives. I am also grateful to the Ronald E. McNair program, Dra. Christina Torres García, Cynthia Dukich, Dr. Jamie Manson, and mentors and friends at EWU who have always supported and inspired me.

Thanks to my colleagues and lab mates, especially Fabiola Pulido-Chavez, Lesly Franco, Amita Banerjee, Alexa Schreier, and Ande Niedzwiecki: you provided me with laughter, friendship, support, love and guidance throughout my graduate journey.

I would like to thank my community of single moms and friends, especially Esperanza Chapman, Shawna Collins, Tricia Cline, Taurmini Fentress, Robyn Fujimoto, Katie Garrett, Daniella Jasen, Jenna Johnson, Celine Maillard, Alicia McDonnell, Kristen Moran, Farah Nadeem, Elizabeth Oesterich, Kathryn Parker, Selene Poulsen, Quinn Redfield, Michelle Salgado, Tommy Shalloe, Kait Shelton, Jessica Sisu, Mayra Villalobos, and my “wife” Joeleen Wilkinson. Special thanks to staff and friends from APEX, especially Elizabeth and Ben Hudson and Joy and Dean Robertson.

Thank you to my family, including my mom Cassie De Abreu, my dad Frank De Abreu, and my brothers and their partners Brandon (Victoria) and Franky (Hunter) for your love and support. To my cousin Kim Pisciotta who is always there to talk when I need her, my extended family and ancestors. Thank you to my chosen family, especially mama Brook Anderson and my “seastar” Raeann Anderson. Without you all none of this would be possible. Thanks to my cats Midnight and Michael for endless hours of entertainment and cuddles during the writing process.

Last but not least, I would like to dedicate this dissertation to my daughter Marina who is constantly inspiring me to be a better person. She has accompanied me on this journey as my witty, creative, and funny sidekick. Marina, you have the ability to accomplish great things with your kind heart and tenacity. Stay humble and reach for the stars!

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Background

Indigenous communities have managed lands throughout the United States for thousands of years (Marchand et al. 2020). Today, tribes lead important ecological work in the U.S., yet Tribal epistemologies used for land management such as "Indigenous Ways of Knowing" (IWK) are often seen as less valid than the Western analytic methods employed by state and federal agencies (Amundson, 1982; Berkes, 2009; Herman, 2016). IWK are holistic, looking at the interconnectivities within the environment (F. Berkes & M.K. Berkes, 2009). Intimate place-based knowledge and holistic environmental thinking have allowed Indigenous communities to manage some of the most sustainable and biodiverse ecosystems on earth (Marchand et al., 2020; Schuster et al. 2019). With climate change a pressing concern, state and federal agencies are seeking new ways to manage dynamic systems sustainably (Berkes, 2009; Marchand et al, 2020).

Indigenous land managers, scientists, scholars, leaders, educators, and climate activists have come to the forefront on climate change and environmental policy and advocacy (Berkes 2009; Doolittle, 2010; Lipsitz, 2008). Calls for Indigenous leadership and partnership with Western institutions have increased, yet in K-12 and college classrooms where future leaders are born, the inclusion of diverse epistemologies like IWK are rare, if not absent (Bang & Medin, 2010). The cultural roots of Western analytic thought are still taken for granted and treated as universal methods of knowledge formation in most educational institutions (Bang & Medin, 2010; Herman, 2016; Nisbett et al., 2001).

STEM education, where Western analytic methods are omnipresent, is an environment where multicultural education is not being advanced, disadvantaging all learners. Learners from holistic epistemological orientations often struggle in educational settings that expect analytic knowledge formation, while learners from Western cultural backgrounds miss an important opportunity to

think critically about the cultural nature of their own cognition (Bang & Medin, 2010; Cajete, 1999; Ngai, 2004; Pirbhai-Illich, 2010).

The inclusion of diverse epistemologies and pedagogies in STEM education is imperative for the advancement of ideological diversity and the representation of historically excluded and underrepresented people in STEM spaces. Innovative and diverse perspectives are needed in environmental science more than ever, as we tackle the complex dynamics of global climate change. Partnership and collaboration with local environmental stakeholders such as Indigenous communities should be at the forefront of efforts to improve environmental education and management.

Environmental and social justice are key tenets of this dissertation. Indigenous people globally have contributed very little to anthropogenic climate change, yet Indigenous communities have and will continue to suffer disproportionate climate-related impacts (IPCC, 2014). Indigenous communities have also suffered greatly due to colonialism, as well as ongoing violations of land ownership, and environmental and human rights (Deloria, 2016). As such, it should be considered a moral imperative that non-Indigenous Institutions seek to partner and collaborate with local Indigenous communities (on their terms) to address environmental matters including education and management.

It is important to note that Indigenous people do not hold monolithic worldviews or cognitive systems, but there is a tendency for Indigenous pedagogies and epistemologies to show holistic character. Holistic epistemologies are also not limited to Indigenous cultures: they are common among other non-Indigenous collectivist cultures around the world. The holistic epistemologies of Indigenous cultures are unique however, in that they are rooted in generations of place-based knowledge about the environment, while being adaptive and dealing with complex and dynamic

natural systems well (F. Berkes & M.K. Berkes, 2009). Finally, holistic epistemologies should not be seen as a binary opposite to Western analytic thinking (Maryboy, Begay & Nichols, 2020), but rather, a different and equally valid way of forming knowledge about the world around us.

The objectives of this dissertation research can be summarized as:

- To describe how Western and Indigenous pedagogies and epistemologies have been employed to tackle environmental problems
- To identify recommendations for Western audiences that promote collaboration and partnership with Indigenous communities on educational, vocational, and policy-level environmental concerns.
- To develop and test tools for teaching holistic thinking to Western Audiences, as part of a multicultural approach to STEM education.

This research has implications for educating the public on analyzing complex environmental problems using a holistic lens which we hope will lead to increased understanding, participation and cooperation between local communities, stakeholders, and scientists. We also hope that this work will be adopted into Washington State education standards on tribes, which will help to educate K-12 students on different ways of viewing the world and environmental matters, elevating the status of IWK and other diverse epistemological lenses, and improving outcomes for students from diverse epistemological backgrounds.

This dissertation is separated into four chapters, using a multipronged approach that explores environmental education, management, and the leadership and collaboration of Indigenous communities in these efforts. The first chapter discusses the importance of incorporating a

holistic perspective and Indigenous voices into environmental science education. The second chapter describes a design-based research study that was carried out over a period of three years, where tools for teaching holistic environmental thinking were designed and implemented collaboratively by a diverse teaching team including University of Washington faculty, graduate students, K-12 educators, and Washington state Tribal educators, scholars, leaders, and storytellers. It describes outcomes and recommendations for classroom application. The third chapter discusses the history of land management and stakeholder engagement in the United States, with an emphasis on how a holistic perspective could be employed by incorporating Indigenous and local community voices. The fourth article discusses Indigenous leadership on climate change action and the importance of including and partnering with Indigenous communities as key stakeholders on climate action globally.

Statement of Positionality

I am the 4th generation born on my mother's side to Norwegian immigrants, the second generation born on my father's paternal side from ethnically Portuguese immigrants from Aruba and the Northeastern coast of South America (Guyana, Suriname and Venezuela), and the great-granddaughter of a homestead family of English/Scottish origin on my father's maternal side, I hold no claims to Indigenous identity and recognize that I hold biases from a Western cultural upbringing. My Indigenous colleagues from Yakama Nation and Colville Confederated tribes contributed greatly to the work in this dissertation, shaping approaches to the research

Chapter 1: Building Environmental Literacy Through Holistic Storytelling

Ecology and Environmental Sciences *in revision*

Abstract

Today, technology delivers information related to our environment, but not the skills of how to form knowledge and wisdom when too much data are available due to technology. Therefore, many environmental problems persist for decades as researchers explore one narrow aspect of the problem, and do not recognize problem interconnectivities. This fosters environmental illiteracy in the environmental decision process. In contrast, the holistic knowledge-forming process of Indigenous People teach their youth to form holistic knowledge of nature and to realize that their decisions may impact 7 generations of their tribe. This prepares each Tribal member to be part of the community-level decision process. Therefore, the concept of STEM science learning should be expanded to include Indigenous STEAM (iSTEAM) to help build environmental literacy.

Keywords

Environmental information, decontextualized management, Indigenous and Local knowledge, holistic stories, wisdom deprivation, Indigenous STEAM.

1.1 Communities as Our Source of Knowledge

Environmental problems of our day are treated as a monolith: separated from inherent political, economic, and societal dimensions. We know this because many approaches have been used to solve environmental problems and yet those problems have continued to persist for decades (Gordon & Berry, 2006; Vogt et al., 1997). Traditional top-down processes isolate external, decontextualized knowledge to inform internal policy and management practices, which ultimately impact local communities and not the decision-makers. These decisions are based on pre-identified solutions which allows decision errors to be propagated throughout the decision process since they are based on framework theories and not local theories that are predictive and refutable (Reason, 1990). These errors are used to justify biased decisions that benefit only a few and not the local community, even when the decision has the potential to result in an environmental or societal catastrophe. This fundamentally weakens ensuing legal and political frameworks because they do not present the context of interconnected issues and relevant stakeholders impacted by the decisions made for each problem. Frequently the top-down approaches represent the views and values of decision-makers and special interest groups with an economic stake in the solutions. They do not give a voice to Indigenous or local people who live close to the land and are the most impacted by these decisions, and who "hold vital ancestral knowledge and expertise on how to adapt, mitigate, and reduce climate and disaster risks" (World Bank, 2019). Who better to collaborate with than the Indigenous people who account for ~6% of the world's population but "own, occupy, or use a quarter of the world's surface area, they safeguard 80 percent of the world's remaining biodiversity" (World Bank, 2019). Most Indigenous groups have preserved global biodiversity sustainably over many centuries, far more than any modern civilization, but are usually only consulted after decisions have already been formalized by management agencies.

This exclusion of communities with local knowledge or those with a different knowledge of a problem is not uncommon when a non-holistic lens is used to assess a complex problem. Taleb (2012) wrote "No time in history of humankind have more positions of power been assigned to people who don't take personal risks." Most decision-makers do not grow up or live close to the land like Indigenous peoples, and rarely experience the negative impacts of their decisions on themselves or on their communities. In contrast, Native Americans have to prioritize their options and reduce the risks of making wrong choices since they depend on their land base for survival. Thus, resource and environmental knowledge populate the center of Indigenous culture as well as their economies. Indigenous economic models prioritize making decisions to first protect the environment, second health, third culture and fourth economic development; sovereignty and cultural resources are also not negotiable if an Indigenous/Tribal Peoples business model is to succeed (IFMAT I, 1993). These priorities are central to Indigenous approaches to resource management and provide a model for reorienting our own approaches to addressing environmental problems. The misalignment of societal values in our knowledge-forming systems is most conveniently observed through recent repudiation of evidence-based science. It was recently published that state and federal governments have been suppressing the inclusion of evidence-based science in decision-making following the 2016 U.S. national elections (Hagel 2020; Rosenberg 2020). This regretfully means that evidence-based science is given less consideration in political decision-making today. This deprivation of evidence-based science will ultimately have lasting repercussions for our security, safety, and health (Rosenberg, 2020). So evidence-based science must be realigned with public priorities and acknowledge the potential impacts it may have on different communities in order to build trust and address environmental concerns. Science is part of the decision-making process but there are many ways of forming knowledge if

the goal is to make environmentally- and socially-just decisions. For example, inclusion of community stakeholders who are most impacted by the problem should be a priority. Fortunately, there are several sources and forms of knowledge that successfully employ these methods with regards to the environment. These models provide a foundation that we can use to build and improve upon our current decision tools.

In the United States, our pursuit of solutions for environmental problems have (d)evolved to be disciplinary focused to form a broader understanding of the natural world. It uses the scientific method to identify predefined solutions that are tested to solve a problem. When Native people interact with scientists they have to translate their holistic knowledge using the western world *scientific method.* This requires them to communicate using a reductionistic method of thinking that no longer represents Indigenous ways of forming knowledge (Marchand et al. 2020). This evolution has prioritized linear evidence-based science and excluded stakeholders at the heart of the issue and the solution resulting in the perpetuation of environmental inequities. Furthermore, these drawn out or neglected environmental problems challenge public engagement, especially in politically contentious and disrespectful circumstances. Thus, we become desensitized and unwilling to participate in the issues that are important to our health and safety. This is not a reality for which we should accept or settle. We have the resources, the capacity, and the decency to acknowledge the value of all voices, and in doing so, to meaningfully impact our future when the appropriate time and investment is committed. These are processes that we need to continually audit and modify as the future presents additional obstacles. Through the right lens, we could achieve holistic resource management and adaptive comprehension for the future that are environmentally, socially, and economically just.

The take-home message we are advocating for is that local communities should be guiding the development of knowledge and co-managing local lands and waters. Environmental problems cannot simply be solved with additional technology. A combination of technology and local expertise is required. The union of technology and societal engagement situates environmental issues at the forefront of our dominant culture and discourse and affirms a plurality of shared experiences. Digital technology in particular is an effective tool in centering local environmental narratives. Cunsolo et al. (2013) showed how digital storytelling is a community-driven methodology that can unite digital media outputs with oral wisdom while also fostering unity among a diverse group of people. They wrote that "digital storytelling is a powerful strategy for engaging individuals who have been historically silenced, marginalized, and/or tokenized." (Cunsolo et al. 2013). In fact storytelling, as part of this tool kit, is how Indigenous People successfully maintain environmental literacy. These knowledge-forming processes are developed at a young age so that Indigenous youth can uphold environmental stewardship and connections to the land. While all cultures develop these storytelling skills, modern industrial societies have displaced us from our stories and broken our link to the landscape. These interconnectivities need to be re-established for a society to make holistic environmental decisions (Ackerman 2020).

Historically, scientists trained in the scientific method were de facto the gate keepers of acceptable scientific knowledge and facts (Weingart and Guenther 2016). Today, this is changing because technological innovations provide massive amounts of data for us to evaluate and utilize. Weingart and Guenther (2016) writes how the public trust in the science is being hurt by technologically-based popular media that competes with science for people's attention. Historically, people not trained in the scientific method and knowledge-forming processes were excluded in the decision process despite the importance of their views in the political process. People unable to understand

environmental problems in a holistic manner depend on others who they trust to be the gate keepers of acceptable facts to search for solutions. Today technology provides us a tsunami of information at a click of a key on our smart phone or computer (Treen et al., 2020; van der Linden et al., 2017). People, therefore, need to identify who to trust to represent their viewpoint since they do not have time to research each problem.

Recently, Indigenous voices are contributing significantly to landscape management issues such as the salmon habitat restoration projects which are being successfully implemented by several tribes collaborating on restoring wetland areas for salmon habitat on their customary lands (Marchand et al., 2020). Also, Citizen Science is providing another important role in the local knowledge-forming process and are trusted by local communities to communicate science in the popular media (NAP, 2015; Weingart & Guenther, 2016). Using a holistic lens to tell stories about environmental problems would expand the role of local communities as producers of acceptable science knowledge. It would also make it easier to identify errors in the decision process that may result in an environmental disaster. A definition of the problem would identify the viewpoints of people who are excluded because they are not members of the institutional power structure, e.g., Indigenous People. The impacts of excluding key stakeholders who are essential to form solutions to a complex, landscape problem is explored in the next section.

1.2 Ineffective Environmental Problem Definition: Northwest Forest Plan Example

For decades, evidence-based science developed by scientists in academia and management agencies provided the scientific evidence and tools to support environmental decision-making processes in the United States. Evidence-based science, however, may not include all the relevant stakeholders and the interconnected problems they introduce into a problem matrix. This process

failure can be seen by examining the Northwest Forest Plan (NWFP), developed in the early 1990's during the Clinton Administration. The plan called for a settlement of the conflicts between commercial logging on federal lands, rural communities dependent on revenue produced by timber cutting on public lands, and the Northern Spotted Owls endangered by the cutting of old growth trees. The Plan was designed to address conflicts on National Forest lands located on National Forest and Bureau of Land Management Districts in Washington, Oregon, and California (Thomas et al., 2006).

Development of the NWFP included over 600 scientists who put forth strategies for all forest species and called for the use of ecosystem management on National Forest lands; Ecosystem management explicitly links the natural and social systems (Vogt et al., 1997). Despite the high number of scientists and the use of a systematic management approach, the NWFP ultimately failed because it was designed to develop a solution only for federally managed public lands and did not address the landscape of diverse stakeholder communities impacted by the conflicts. The NWFP fractured stakeholders into two divisive groups: Environmentalists who wanted protection for the Northern Spotted owls and old-growth forests; and Forest professionals/rural communities who worked as loggers, truckers, and operators at local timber mills. Voices that were not included were the forest professional/rural communities who faced a significant impact on their local economies since the NWFP decreased timber cutting by 80% from the National Forest lands (U.S. Forest Service, 2020). This cultivated a toxic situation in which stakeholders were discouraged from engaging with each other. The problem continued to fester but was not resolved.

The 1994 Northwest Forest Plan was a solution designed to protect old growth forests, endangered species, and provide a predictable level of timber harvesting from National Forests to support the economies of rural communities (Thomas et al., 2006). However, the NWFP failed to address

economic and social goals because it did not include all the relevant stakeholders and include the trade-offs each stakeholder group needed to make. The Plan focused on responding to a problem that a court injunction triggered, e.g., halting timber cutting in National Forests to address the protection of endangered or listed species by the Endangered Species Act (ESA). Spies et al. (2019) identified key findings of the 1994 Plan that explain why it could not achieve its goals - "threats to biodiversity lie beyond the control of federal land managers" and a clear need for collaboration among the multi-stakeholder communities. To address the economic and social goals would have required a collaborative process among multiple stakeholder groups and the diverse array of landowners who were all impacted by the decisions to protect endangered species.

A follow up story to the 1994 Northwest Forest Plan emerged 26 years later but on Washington State trustee lands. A lawsuit was filed in late 2019 and early 2020 by a timber trade group and an environmental coalition against the Washington Department of Natural Resources (DNR) (Bush, 2019; Bush, 2020). In the lawsuit they argue that DNR is not adequately meeting its fiduciary responsibilities to rural communities by the level of timber they were cutting from Washington's trust lands. The rural communities involved in the lawsuit are the same groups who were actively involved in the early 1990s National Forest conflicts that failed to address the economic and social impacts on rural community livelihoods. If the early 1990s planning process had been holistic, and not a top-down approach to assess the tradeoffs between different stakeholders impacted by the Plan, this problem would not be re-emerging today.

These conflicts reveal the juxtaposition of urban and rural environmental values. Bonnie et al. (2020) note that rural communities have a stronger place-based identity compared to urban or suburban Americans. This report also identified different environmental issues that rural communities prioritized and felt needed protection. They also found that rural communities prefer

policy to be "overseen by state or local government and that allow for collaboration with rural voters and stakeholders" (Bonnie et al., 2020). The prioritization of local expertise is also reflected in preferences of news. Since the 1980s, the public had become more skeptical of journalism, characterizing it as being more biased, less honest, and not caring about the public (Pew Research, 2017). Many Americans prefer to get their news from local media outlets that they trust more than national news outlets (Pew Research Center, 2019). This means that community centers are more trusted, be it the rural communities or in the urban centers. This finding reflects a greater trust of local knowledge and is why the appropriate voices need to be heard when framing problems around multi-cultural and diverse landscape ownership patterns. Resolving environmental issues that are experienced and perceived differently should be guided by stakeholder approaches in a bottom-up manner. Without the incorporation of stories and perspectives of all appropriate stakeholders, conflicts will continue to persist even with legal settlements.

As local communities were developing greater skepticism about journalism, so too did their criticism of environmental credibility. The 2014 Shellenberger and Nordhaus essay, entitled 'The Death of Environmentalism', presented a very negative view of western environmentalists and its decadal years of failing to include humans and economic development in addressing climate change impacts on the environment. Cohen (2006) summarized how the Shellenberger and Norhaus essay defined environmentalists as addressing issues too narrowly, not engaging with the public concerns on environmental issues, and not responding to the political interests held by the environmental organizations. This has contributed to the public not being engaged on environmental issues (Troumbis, 2017). This is the foundation of Western environmentalism that, to this day, neglects and disrespects local voices of community members as well as long-term Indigenous knowledge of nature (Goldman, 2020; Wright, 2020).

Environmental mismanagement also proliferated and created unintended consequences for forest professionals/rural communities as the public turned away from the forestry profession and how they managed forests for a singular purpose. This caused the emergence of a new story of how to manage forests, i.e., 'New Forestry'. In the early 1990's, Forest Service scientists and academic researchers led the change in forest cutting practices towards long-term health and productivity as well as national forest management agencies adopting the ecosystem management paradigm (Vogt et al., 1997). Gordon (1994) describes this paradigm shift as focusing federal agencies to: manage where you are; manage with people in mind; manage across boundaries; manage based on mechanisms instead of algorithms; and manage without externalities. Although the paradigm shifted, the tools to implement ecosystem management were still not adequate and did not include local communities in planning.

The persistence of environmental problems is a result of managers accepting limited solutions to address problems identified by local communities in forests. The Northwest Forest Plan, which was supposed to solve a complex problem in the early 1990s, is a reminder of these inadequacies. Their message was scientific assessments need to incorporate the central stakeholders and derive wisdom from the local communities. There is no singular solution for environmental problems that affect communities differently. They need to be at the center of these discussions and drive our approaches. As we live in this age of massive digital media, it may be difficult to motivate public engagement on environmental issues, though it is the responsibility of environmental leaders in conservation to maintain transparent and malleable practices to the interest of the public.

1.3 Environmental Knowledge Formation: It's Not Just for Scientists

Fundamentally, it is a scarcity of knowledge that is depriving balanced and just decision-making. Natural resource management decisions are made every hour using only a fraction of the facts available for addressing environmental concerns. These decisions are not only made with a dearth of information but also a lacking of knowledge about holistic connections which consequently results in poor assessment protocols. These weaknesses contribute to the persistence of local and global environmental problems with no clear solutions in sight. We contend that standard assessment processes and approaches fail to produce viable solutions because they lack holistic connections. These tools tend to simplify a problem as input factors are pre-selected for each assessment; this is well described by Meadows and Wright (2008) in their book entitled 'Thinking in Systems.' "Scientists and science educators have long wrestled with the challenges of communicating evidence that contradicts people's personal, religious, or political beliefs, particularly regarding evolution, vaccine safety, and climate change" (Gross, 2018). In today's data intensive and technological world of many environmental problems, individuals should learn skills to holistically understand their environment, to be environmentally literate, and to be able to contribute to the competitive workforce of the United States. These approaches are often determined exclusively by evidence-based knowledge provided by scientists. It excludes or dismisses local voices and other sources of credible community knowledge since it is not formed using the scientific method. While scientists offer valuable data and insight, they are only one component of the decision-making process.

Holistic knowledge that enables an understanding of complex systems, and their relationships over variable spatial and temporal scales is crucial for environmental literacy. Indigenous People, however, have a knowledge forming process that provides solutions to environmental

issues through long-standing expertise. "The main knowledge-holders of the site-specific holistic knowledge about various aspects of this diversity, Indigenous peoples, play a significant role in maintaining locally resilient social–ecological systems" (Green and Raygorodetsky, 2010). Indigenous Peoples are particularly acute at making environmental and natural resource decisions because they are able to prioritize environmental health and cultural issues separate from economic gains. They use holistic critical thinking that includes knowledge held by a tribe for many generations. Indigenous knowledge is transmitted through stories that have a moral (Marchand et al., 2020). This allows for more ethically-grounded environmental literacy and planning. These knowledge forming processes are more adequate for addressing complex environmental issues and necessitates that Indigenous People and those with a place-based lens need to be recognized and engaged as decision-makers for the environment.

When we talk to natural scientists about the holistic knowledge-forming process of Native Americans, we were occasionally asked 'Where is the science?' Such a response indicates a lack of recognition for the many different ways of forming knowledge that should be included alongside evidence-based science in the decision-making matrix. Such a question would not be asked if the general public were more engaged in the knowledge-forming process used to assess the sustainability of land and natural resources. Johnson (2018) wrote that science should not be *owned* by a select group of people who indirectly control access to and assimilate knowledge simply because of the degrees they hold or their disciplinary-based jargon that few understand.

From a western world perspective, it probably seems strange to think that one can write stories about science and translate all of its complexities. Western European stories were written as fantasies or imaginary worlds where the 'good' people overcome 'bad' people and class structure doesn't matter as a person born on a farm can become the leader of a country, e.g., win the

attention of a princess by being clever and beating the bad people. These stories were not written to tell a morale tale or teach ethical behavior in nature. They were written to entertain the reader and to escape the trials and tribulations found in our world (Gottschall, 2012). This contrasts Native American tribes where stories entertain but also deliver a moral held by the community.

Since society is impacted by decisions related to the environment on a daily basis, they need to learn to tell stories on environmental issues to ultimately take part in the formation of knowledge. It's the scientists' responsibility to adapt, to grow their skill set to include different modes of knowledge acquisition, and to include the general public in science tutelage. Increasing general scientific knowledge doesn't take anything away from the need for research scientists to interpret and present our scientific understanding of the environment. However, if we don't figure out how to situate holistic science in popular culture, the environmental decision-making process will continue to be politicized with researchers isolated in silos, perpetuating the exclusion of local place-based knowledge in environmental discourse. Society ultimately needs the tools to engage in holistic knowledge formation because environmental problems traverse many borders and thus diverse communities around the world experience a multitude of environmental issues.

As Morris et al. (2013) write, people are not born with scientific thinking skills and learn these skills as they are "scaffolded via educational and cultural tools." Therefore, tools are needed to easily and critically contextualize science knowledge and to develop a process that teaches these thinking processes to citizens even without specialized science degrees. Building a new approach is senseless since Indigenous people have taught the skills discussed in the NRC (2010) report to their youth for hundreds of years. Indigenous knowledge weaves understanding of the natural world through storytelling and engenders necessary holistic skills of creativity and problem-solving skills that young children need to know. These efforts reinforce a fundamental shift from

training *environmental technicians* who tweak a small part of the landscape in response to a problem to producing *environmental leaders* who are able to contextualize a problem.

Native People also have a remarkable approach to environmental education that is grounded in long-term knowledge of the land and waters through understandings of reciprocity and dignity for the natural world (INUIT, 2015). Native youth develop environmental literacy skills as they grow up and are commonly taught to think of seven generations and ask how past generations would have addressed a problem (Marchand et al., 2020). This education instills *bottom-up* approaches to the environment that focus on describing each problem in a holistic, interdisciplinary lens that creates cultural foundations. This thinking has resulted in the prominent inter-Tribal collaborations in restoring and protecting critical salmon habitat in the Pacific Northwest (PNW) U.S. (Goldfarb, 2018). Regretfully in most communities today, we are not teaching our youth the environmental leadership skills and tools that they need, but rather persisting to educate environmental technicians who will consistently produce the same solution for every problem. Current technicians gather data that are not contextualized to the problem and unfortunately frequently address the symptoms of the problem using a narrow set of prescriptions commonly mandated by a single organization or agency. In contrast, strong environmental leaders use a contextualized lens that is based on place-based knowledge that interconnects multiple factors: cultural values, the environment, health and conventional economic valuation.

Probably the most important factor why we need Indigenous stories today is that they have a knowledge system and cultural traditions that give them an early warning that an environment is not in balance or will be negatively impacted by climate change. In Australia, aboriginal knowledge has been used to manage lands before climate change impacts were evident to scientists, e.g., using fire to manage grasslands so kangaroos and other animals would have

nutritious, green grass during a drought (Gammage, 2013). Their traditional hunting practices fostered a diversity of animals surviving in nature and their removal as managers resulted in the extinction of many species (Bird et al., 2012). Leonard et al. (2013) describe how the Gija people "believe changes in the weather result from human activity and are not a matter of change." and tell stories explaining the weather events that they experience. When Leonard et al. (2013) asked the aborigines to explain why a land was not productive and had dried up, they explained it as the loss of traditional owners who knew how to manage the land and water. Their knowledge goes back thousands of years and is holistic. Recently aboriginal knowledge has been used to develop Indigenous climate change adaptation planning to address future climate change impacts (Leonard et al., 2013).

1.4 Science Literacy is an Information Problem

There is a perception that assessing and analyzing large data sets are something that scientists should provide after they have completed many years of training and education. Scientific knowledge is generally accepted by decision-makers because standardized statistical criteria are used to validate the truth of predicted outcomes (Marchand et al., 2020). This propagates the perception that knowledge formed by the general public or passed down through stories are not realistic or credible unless proven true through the scientific process (DeLoria, 1997). But holistic environmental stories are harder to tell using the western science method because only a subset of the information. Therefore, due to the scarcity of knowledge, the underlying cause of the problem or its surrounding interactions are not revealed. Since in the scientific methodology the endpoint is always premeditated, the process can be adapted to reach the pre-defined endpoint. If guided by the correct pedagogical platform, we contend that individuals can be taught to use technological

tools to assess complex environmental problems in a holistic manner, i.e., contextualize within environmental dimensionality.

Holistic knowledge-forming process as practiced by Indigenous people address one of the challenges that western scientific method has not resolved, e.g., converting massive amounts of digital data into environmental wisdom so these problems do not persist for decades. This is especially important today where the public do not have the tools to decipher and form data interconnectivities. The title of this paper describes this situation well - "Information Paradox: Drowning in Information, Starving for Knowledge" (Orman, 2015). The comparison of the differences between information, knowledge, and wisdom is diagrammatically shown in Figure 1.1. Attempting to form knowledge without understanding the strengths of the connections between diverse pieces of data is not very useful. Similarly having knowledge based on only one part of the system does not allow you to make trade-offs for a problem. Holistic storytelling links environmental problems across time and space, including all the problems linked to it and encompassing all stakeholder groups impacted by the problem.

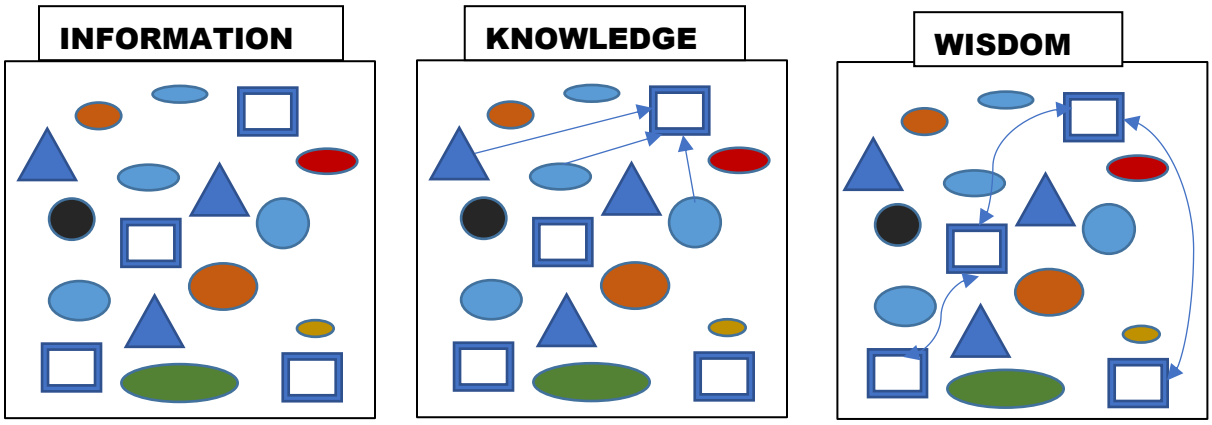

Figure 1.1 Diagrammatic representation of complex socio-ecological systems with too much [left] information but little interconnected knowledge so individual data points cannot be used to understand nonlinear behavior or to tell a story, [middle] connecting information to form science knowledge of the local ecosystem using pre-determined facts, and [right] holistic stories interconnecting information using knowledge from the past to form wisdom of local ecosystems.

Living in the industrialized world has detached us from the land and thus our ability to understand and tell wisdom stories from the massive amount of information we are exposed to each day. The linear approach does not work primarily because it presumes that we have sufficient knowledge to form solutions despite our incomplete, or lacking, knowledge of any given issue. When most of the authors of this article were growing up, stories and TV shows used to have more morals in them. Now much of what is offered today is banter and slapstick comedy. This strays away from some of the most intricate ingenuity that has grounded histories, cultures, and identity for ages. Environmental literacy or just decisions do not work in a linear storytelling world since it moves us to a predictable and predetermined end-point. In many instances our society has promoted linear stories only to realize later that these narratives are telling a mere fraction of the actual story and has even advanced us in the wrong direction. An iconic example includes Smokey the Bear [Figure 1.2], an icon created to sell a story which was incredibly successful in pushing the United States towards a policy of complete fire suppression. Unfortunately, we did not incorporate into the story available knowledge from generations of Native forest stewards of this land who used fire as a means to keep the forests healthy. Today we are still remediating the problems wrought by this misinformed policy of fire suppression.

Figure 1.2 1989 Smokey the Bear poster. ***Source:*** **National Agricultural Library.**

Teaching science literacy today needs to teach "the interconnected nature of fundamental concepts for earth, space, life and environmental sciences" (Maryboy et al., 2012). Since science is taught using a narrow disciplinary lens, it de-contextualize information and thus is unable to teach science literacy skills to the non-scientific community. As Reyes-García et al. (2016) summarized: "scientific knowledge … goal of being universal, transferable, mobile, and not tied to a singular place." This is a very linear thinking approach to forming science knowledge where some disciplines dominate the discourse. This mental construct of science today can be viewed as a seesaw that moves you up and down at the same spot and leads a decision-maker to adopt a pre-determined end-point or solution. In contrast storytelling allows a community to form holistic view of the world "emphasizes the historical continuity of such bodies of knowledge, not

only their local embeddedness, a characteristic that seems to contribute to the long-term resilience of social–ecological systems by providing a pool of information and practices that improves societies' adaptive capacity to cope with recurrent environmental or social disturbances" (Reyes-Garcı´a et al., 2016). Indigenous stories already include multiple interconnections between "earth, space, life and environmental sciences" (Maryboy et al., 2012). Linear approach to science are difficult to use to tell stories of interconnected knowledge. Indian Country Today (2018) describes these differences: "With linear thinking, we rely on logic, institutions, and others to try to protect ourselves. Circular thinking originates from the earth, the universe, and the Creator; we are all connected and all safe."

1.5 Native Oral Storytelling Traditions of Nature

Storytellers, like the Native American tribes, tell holistic stories about their environment that are grounded in place, values, and principles (Marchand et al., 2020). In his 2012 book entitled *Storytelling Animals: How Stories Make Us Human,* Gottschall wrote that stories are what makes us human (Gottschall, 2012). Stories are what ground us to each other and connect us to our histories. As King writes in *The Truth About Stories, "*that's all we are" (King, 2003). Stories inherently shape the ways we see and know the world as well as how we live in it.

Native people's stories are similar to a mystery novel where pieces of evidence suggest who are the 'bad' players while revealing bits of information that ultimately reveal knowledge to recognize who are the guilty parties. It was also a way to tell a story that could have several different endings, so they became learning moments for Tribal youth to learn to respect nature, how to live on the land that includes its cycles of change, and how to read the land to reduce its vulnerability to land-uses. In Native American stories, animals and humans can transform into

other shapes (Dove, 1934) and conclusions are not predictable or repeatable. Sometimes the coyote - a trickster - is a common animal in these stories as described by Jay Miller (Dove, 1934):

> "He embodies *all* the human traits: laziness and patient industry or frantic exertion; foolishness and skillful planning; selfishness and concern for others...he is the incomplete and the imperfect...Coyote has fur, and it is the incomplete and it is fun to hear about him and his exploits. What he lacks in dignity he makes up in sheer exuberance."

Native Americans have long oral traditions that transmit knowledge that is transgenerational and may include descriptions of natural phenomenon that are important to know to live in balance with the natural world. They continue their storytelling practices, even after they were forcibly removed from their lands. Oral storytelling has kept their customs, values and languages alive within the Tribal community.

It is important to recognize that the characters of the story are not as important as the knowledge that is being transmitted by the story. For example, there is a Native American Wisdom Story about how before the arrival of humans, the world was dominated by a monster who was eating all the animals in its path. The coyote tricks the monster into swallowing him after he had gathered some flint and a knife, so he could then set fire to the monster from within to kill it [Figure 1.3]. The monster Wisdom Story is highly relevant for today's society even though a monster aimlessly swallowing animals has no literal connections in today's world. Many Indigenous stories are expressed similarly through a context of relationality, orienting the reader within a world of networks and connections (Kimmerer, 2013). Through this interpretive ambiguity, each individual

can therefore "generate meaning within their own lives" (Simpson, 2014). This is particularly true when positioning the reader through the lens of the trickster. In this story – the coyote— who can be good, or sometimes bad, uses a novel approach to kill a monster and save many animals.

Figure 1.3 Student from Holistic Storytelling course at the University of Washington illustrates the Coyote wisdom story. From the mouth of the Monster, the Coyote works to save the animals. While often excluded, the coyote brings external perspective to addressing collective issues. In the end, the monster's body is redistributed amongst the four directions revealing a reciprocity associated with environmental responsibility to the earth.

Similarly, the Nordic tales have a trickster– Loki– who was jealous of the Nordic Father God's son, Baldur. The story recounts how Loki tricks the blind brother of Baldur into killing his brother using a piece of mistletoe. This is a story that describes how even a small and insignificant thing– in this case, the mistletoe– should not be ignored. The trickster serves as a change element that

drives the story in a different and unpredictable direction. Many contemporary stories would benefit from this model as they tell predictable linear narratives that give security and closure, ideals that we find comfort in. The inclusion of a trickster in stories reflects the unpredictability of life and demonstrates that we must learn to be amused by the antics of a trickster while expecting these unexplained events. We can't control the environment and embracing the story element of a trickster can help emphasize such valuable take home messages.

The Creation Stories told by past societies more than a 1,000 years ago are just as relevant today as in the past. These stories frequently include a tree at the center of the world and recognizes the importance of trees for human survival. Trees are used as symbols of science, culture, politics, religious enlightenment, and knowledge: Ancient Egypt incorporated the Sycamore tree in their stories, the Ash tree is found in Nordic mythology, the Mulberry tree in China, the Oak tree in parts of Europe, Buddhists have the Fig tree, the Montezuma cypress in Mexico, and there are many more examples from around the world. To understand why trees are central to so many creation stories, it is vital to realize the resources that all trees provide to societies: medicinal products, foods, spices, heat, rubber, chewing gum, insect repellent, housing, and even hallucinogens (Prance et al., 1993). Arguably, the most important role of trees is that you will find fresh drinking water where you have trees, i.e., today 75% of the world's freshwater comes from forests and 90% of the world's cities rely on forest watershed for their water (FAO, 2020). There are plenty of reasons to tell stories about forests globally.

Embedded in these stories are tales of the importance of respecting nature and managing environments as an ecosystem. The terms used to describe the science of forest management are derived from Silvanus— a Roman God of Forests, Groves, and Wild Fields— who presided over those parts of nature and had knowledge on how to cultivate a forest (Smith, 1867). Trees included

in these stories lived for over 1,000 years and provided survival resources for multiple generations of people who learned about them through stories passed down through the generations.

Tree stories need to be told in our global industrialized world where many lack any knowledge of forest products or forest ecosystem services. This leads to the over-exploitation of these resources due to ignorance and lack of environmental literacy. Many trees mentioned in creation stories are endangered today, and, except for the local people who value them, the rest of the world frequently doesn't know about them or value them. For example, the Dragon's Blood tree is only found on a remote island known as Socotra off the coast of Yemen and was first discovered by the East India Company in 1835 (Gaffney, 2019). According to legends, the first tree was created from the blood of a wounded dragon and, correspondingly, the latex released by the tree's bark has medicinal values for local people (Bulnes, 2017). Today, the latex from Dragon's Blood trees is sold in international markets as a cure for many human ailments (Xin, 2011). Unfortunately, these trees are now endangered and over-exploited as a result of ignorance and miseducation.

Creation stories often focus on trees that are important survival resources for Indigenous communities. One only needs to look at trees that were and are still revered (Coder, 1995). One positive outcome of the creation stories is that they commonly set rules for how society should function related to nature. This lessens the chances of assured societal collapse when nature is over-exploited beyond its carrying capacity. As an example, some of those rules fostered the establishment of sacred groves by the societies such as the Hawaiian *wao akua* or the Ethiopian *hujub (*Cardelús et al., 2013). These sacred groves are areas of land and forests protected and revered by the local communities. Some sacred groves have persisted for over 1,000 years while, in contrast, protected areas managed by western science have been around for 150 years and are

often fraught with conflict. Will the western protected areas still be around in 50 years when no local community respects and protects them for the survival resources they provide?

Storytelling provides us with an opportunity for a holistic understanding of our natural resources and a more engaging one as well. Storytelling is a door to provide us environmental leadership that communicates complex knowledge that needs to be part of the world's global culture. It is not the property of a select group of people but needs to be practiced by all of us since nature is not a bounded system controlled by a small group of people for their own benefit. It may seem that we are no longer interested in contextualizing the information that is so readily fed to us through digital media, though humans are originally storytellers. It was forecasted several years ago that Americans would no longer read printed books in the future as they would be considered old fashioned/old technology; but this demise has not occurred. In fact Americans still prefer to read printed books and at an even higher level than books in digital format (Perrin 2016). This provides some evidence that society has not shifted into only living with, and learning about, what is dictated by the digital media. Utilizing contemporary techniques to storytelling through digital media may be the future for environmental engagement in popular culture.

1.6 Concluding Remarks: Indigenous Holistic Storytelling - A Critical Element for Environmental Leaders and Policy Makers

There is a widespread perception that the stories and cultures of past societies are fictitious and less relevant today because society has progressed so far and we now live in a globalized world. What is culture when we live in a society where environmental stories are written and packaged by people who are not part of the community? What happens when stories do not organically emerge from their community and are instead manufactured by an outside culture comprising very

different values? If we are going to solve local environmental problems so they do not persist for decades, learning native oral storytelling traditions is crucial to form wisdom from massive amounts of data that technology delivers us daily. Some suggest that Indigenous People are no longer linked to their land and Tribal community since so many live in urban areas. Data show that 78% of American Indians and Native Alaskans live outside of reservations or off-reservation trust lands in 2010 (Norris et al., 2012). Despite this, urban Indians continue to return to reservations to maintain a link to their cultures and make decisions using the consensus-based decision-making process employed by most Tribal councils in the PNW U.S. Native communities live in both worlds – within the global economy as well as their local cultural environment. For Native People, reservations maintain community, culture, and their stories. For these reasons, the loss of culture may not be as widespread as some people think.

Pacific Northwest tribes are successfully providing leadership on environmental and resource issues; most issues cross geographic and political borders and are important for all of us in the pursuit of biodiversity conservation and a healthy environment. They are using the knowledge passed down through stories inter-generationally and youth learn about sacred places, conservation and wildlife (Conniff, 2013). When this knowledge is not part of environmental management, animal populations may go extinct (Bird et al., 2013) or we lose the tools to manage the negative impacts of climate change on the environment. Indigenous and local people are effective at providing early warning of climate change impacts before scientists recognize that an environmental problem is looming (e.g., Jones, 2020). Without including the holistic stories of Native communities, we face a scarcity of knowledge to address climate change issues or recognize that a problem is emerging.

Our greatest challenge today is how few people are literate in a holistic science decision process. Students, citizens, and politicians lack the science literacy skills needed in today's information economies (Morris et al., 2013). Science literacy is not just being able to remember facts but an ability to critically evaluate, contextualize, and determine what science data are needed to address a problem generated in our information world. Science literacy in education has been described as teaching "adaptability, complex communication/social skills, nonroutine problem-solving skills, self-management/self-development, and systems thinking" to meet the challenges imposed by our 21st century information economies (NRC, 2010). Most educational programs do not teach these skills (Plutzer et al., 2016). Thus, science knowledge becomes the 'hidden half' of the information economy. Even when decision-makers recognize they need to include science in solving an environmental problem, it is too narrowly defined so its ecological, social or cultural scale and context are not made transparent. It is not an option to avoid including the sciences in today's information-based economies since "science is part of the wonderful tapestry of human culture, intertwined with things like art, music, theater, film and even religion." (Johnson, 2018). Science literacy is not just for scientists but contain essential skills needed by students, citizens and politicians. People need to make decisions in a realm where science, technology, engineering, math and the arts all intersect (Weingart & Guenther, 2016).

Youth need to become environmentally literate but are less attracted into science fields in the U.S. Science education needs to attract a more diverse group of students and to keep them engaged in the educational process. Science education should consist of youth helping to create knowledge instead of just being given knowledge they need to learn. Not only scientists need skills to address science-based problems, but non-science employment sectors need employees who are grounded in STEM education knowledge (Hines et al., 2013). Private sector businesses

also want to hire employees capable of applying "abstract, conceptual thinking to "complex real-world problems—including problems that involve the use of scientific and technical knowledge—that are nonstandard, full of ambiguities, and have more than one right answer" (Alberts, 2013). Many students do not link science literacy to be gainfully employed in today's information economies. It does not help that market economies have a poor record of accomplishment concerning environmental issues and sustainable consumption of natural resources.

Certain demographic groups (e.g., Hispanics, African Americans, American Indians, and Alaska Natives) who have a family or clan history of looking at the environment holistically are not attracted into STEM educational programs; they account for a quarter of the U.S. population but 11% of STEM degree holders (Ferrini-Mundy, 2013; Stem-overview, 2017). Few STEM programs are contextualized to include holistic forms of knowledge, e.g., spiritual as well as art, plants, animals, geology as well as physics, or tools to critically think about knowledge across disciplines. The concept of STEM has been modified to integrate with the Arts in education and we suggest that this should be further expanded to **iSTEAM** or **Indigenous STEAM**. This is the case we hope to make in this article.

Today, climate change may finally push us towards recognizing alternative knowledge streams to solve environmental problems; scientists globally and the European Union are calling this a climate emergency that urgently needs solutions (Freedman, 2019; Rankin, 2019). When societies have taken a narrow view of their environment or over-exploited their resources, they collapsed (e.g., the Khmer Empire, the Maya, Nazca) (Haug et al., 2003; Janssen and Scheffer, 2004; Fagan, 2008; Kummu, 2009; Cartwright, 2014). Collapse is not an option but adopting new ways to form holistic knowledge is a viable option. Despite advances in scientific knowledge, environmental

problems have continued to persist for decades, with the exception of a few sparse success stories. This is paradoxical since, in the industrialized world, scientific knowledge has built our information economy. Today, the fragmented use of science to teach science literacy does not allow science knowledge to be used effectively to respond to environmental, economic, and social boom-and-bust cycles (Taleb, 2012; Marchand et al., 2016). Also the standardized tools commonly used in the sciences are not designed to "…acknowledge the value system and cosmological context within which this traditional knowledge was generated" (Houde, 2007) and therefore unable to integrate Indigenous knowledge except as a narrative in research.

To help resolve environmental problems in a shorter time with long-lasting solutions, we need to teach society a process to contextualize the massive amounts of data delivered by mass media. Society needs to process and engage with this massive data holistically by scripting stories of environmental issues. This is environmental literacy utilized by Indigenous people since time immemorial to maintain sustainable relationships with the land. Indigenous storytelling serves as a model for non-Tribal people to develop comprehensive understandings of the environment and thus more effective management solutions. We believe that by teaching individuals, especially youth, digital environmental storytelling, we can help guide society toward a holistic perspective for solving complex environmental challenges. When more members of our society begin intuitively considering multiple angles of an environmental issue and accepting the unpredictability of the environments around us, it will be much easier to solve our environmental problems and put us on the path to making even better decisions for policymaking

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Chapter 2: Teaching Holistic Environmental Thought: A Classroom Approach

Submitted to Thinking Skills and Creativity

Abstract

Climate change has exacerbated environmental problems worldwide, exposing the inadequacy of land management plans designed to function best under stable and predictable circumstances. Scientists and land mangers have begun to seek out new approaches, with Indigenous land management practices receiving considerable attention.

Despite this, the epistemological roots underpinning Indigenous land management are largely excluded or marginalized within Western institutions. In educational settings, analytic thinking - a hallmark of Western science, is treated as an objective epistemology, despite research showing that cognitive frameworks vary by culture. Holistic knowledge formation, central to Indigenous pedagogies, is often derided as unscientific. As such, it is usually relegated to the humanities and excluded in STEM research and education. This may contribute to the lack of cultural and ideological diversity in STEM fields like environmental science, perpetuating ineffective environmental practices through stagnation.

In this study, a design-based research approach was applied to a university-level environmental science course at the University of Washington (UW) over a period of three years to develop a framework for teaching holistic environmental thinking. Curricular interventions including digital storytelling, storyboarding, game development and more were assessed during the course. The teaching team consisted of UW faculty, graduate students, K-12 educators, and Tribal

scholars from the Confederated Tribes of the Colville and Yakama in Washington state. Indigenous guest speakers and engaging curricular tools had a positive impact on student ability to understand and demonstrate holistic environmental thought.

Keywords

Holistic Thinking; Environmental; Indigenous Knowledge; Education; Design-Based

1. Background

1.1 Holistic Thinking and the Environment

Research in cultural psychology has shown that cognition and perception depend on cultural context. Socio-cultural and cognitive lenses are developed in childhood through both formal and informal learning and impact the way we perceive the world and solve problems (Vygotsky, 1978, Nisbett et al., 2001). Nisbett et. al developed a theoretical model to describe the differences between cognitive processes common in collectivist and individualist cultures (2001). They reported that individualist cultures tend to use an "analytic" cognitive process, viewing the universe as comprised of discrete objects with set properties, while collectivist cultures use a cognitive process that is "holistic", viewing the universe as comprised of interconnected elements and relationships (Nisbett et al., 2001). While our work juxtaposes these two systems of thinking, they should not be viewed as ideological opposites, but rather as different "epistemological orientations" (Bang & Medin, 2010) that are more common depending on the socio-cultural and educational upbringing of the individuals that use them. These systems developed throughout human history in response to the demands of historical, geographical, and

cultural settings, allowing people to adapt, survive and solve problems specific to the context in which they were developed (Nisbett et al., 2001).

In the United States, differences between Tribal land management and western land management have been documented by scholars, with recent emphasis on how cognition, culture, and decision-making processes impact environmental planning and practice (Marchand et al., 2020). Tribal management tends to be holistic, focusing on how systems function together over an extended timescale to build resilience; utilizing local place-based knowledge passed down through generations; and considering humans as enmeshed with and reliant upon the environment, while taking cultural, economic, political, and scientific matters into account (Marchand et al., 2020). In contrast, public lands in the United States are managed in the Western analytic tradition, where scientists and land managers work together to identify problems and probable solutions, often scaling up localized research to larger areas, or using predictive models to evaluate change and disturbance over time.

Western analytic thinking can be traced back to Greek philosophy and Cartesian rationality, bodies of thought which emphasize methodical and objective quantitative analysis (F. Berkes & M.K. Berkes, 2009; Herman, 2016). Inquiry methods favor linear cause and effect relationships, discrete classification, and controlled, replicable experiments. Binary conditions in hypotheses seek to derive simplicity from complexity, and statistical analysis on the properties of smaller sample populations are often used to make educated assumptions about larger systems. (F. Berkes & M.K. Berkes, 2009, Marchand et al., 2020). This approach tends to be reductionist, looking at narrow pieces of information, rather than holistically addressing a problem embedded in a system (Young et al., 1996).

Indigenous environmental practices stem from Indigenous Ways of Knowing (IWK), which are qualitative and holistic in nature. IWK refers to the knowledge-building process (F. Berkes & M.K. Berkes, 2009) as well as the body of knowledge gained through time by Indigenous societies. IWK are derived from an intimate history of the local environment and built upon spiritual beliefs and cultural practices (Kimmerer, 2002). Holistic epistemologies and pedagogies have been used by diverse groups of Indigenous communities for thousands of years to sustainably manage the environment (Marchand et al., 2020).

Indigenous cultures today are responsible for protecting 80% of earth's biodiversity while making up only 5% of the human population (Schuster et al., 2019). In the United States, tribes have had to manage very limited tracts of land productively to balance economic, cultural, and environmental sustainability and growth trade-offs. Tribal managers use an analytic approach to address problems, frequently partnering with Western agencies and scientists, but it is within the context of a wider holistic framework for environmental management. This collaborative approach and adaptation to include cognitive tools from Western culture is a form of syncretism that has benefited tribes in many ways, including the ability to win over non-Tribal support for environmental causes (Berkes, 2009; Lipsitz, 2008; Nadasdy, 2005).

Despite a growing recognition of the benefits of the holistic environmental practices that Indigenous people employ, Western educators, scientists and land managers have struggled to see the epistemologies and pedagogies upon which they are built as being legitimate, frequently comparing other systems to Western models, and classifying them in an ethnocentric manner (Amundson, 1982). A holistic approach cannot be appropriately employed simply by trying to recategorize it under a new branch of Western environmental methodology. These ethnocentric frameworks for science and knowledge formation delegitimatize Indigenous epistemologies and

have resulted in Indigenous groups being excluded as stakeholders and sources of knowledge in environmental decision making, both historically and in modern times. While scientific inquiry and analytic processes can yield very specific and detailed information about the environment, they should be seen as one tool for understanding the environment, rather than the full toolbox itself. A holistic approach to environmental management has been shown to address the challenges of managing highly complex and dynamic environments. This is something that analytic approaches frequently struggle with because of their partiality toward controlled replicable systems (F. Berkes & M.K. Berkes, 2009; Gadgil et al., 1993).

In recent years, there has been recognition that Western Science alone cannot solve the complex and pervasive environmental problems we are plagued with today (Marchand et al., 2020). Narrow environmental prescriptions derived from de-contextualized pieces of ecological systems have failed to appropriately address the environmental complexity that is at the core of many of these problems, reducing ecological resilience and sustainability over time (Holling & Meffe, 1996; Marchand et al., 2020). Changes to disturbance regimes because of global industrialization, combined with ineffective land management practices is a recipe for ecological disaster. Environmental concerns have begun to impact economic and political institutions for countries located around the globe, resulting in a search for sustainable solutions to these complex problems (IPCC, 2014; Herman, 2016; Whyte, 2016). For these reasons, the ecological methods of Indigenous cultures and IWK have finally been gaining recognition as valid ways of understanding, managing, and sustaining the environment (Kimmerer, 2002; Marchand et al., 2020). Western managers and scientists have begun to see Indigenous groups as valuable stakeholders and partners for environmental management. Yet, even as they advocate for working with Indigenous land managers, Western scientists and managers have been slow to

adopt holistic thinking as a valid model within their own practices. This may help to explain why educators have not yet developed a model to teach holistic environmental thinking to Western audiences.

1.2 The Educational Context

While Western science can be lauded for many accomplishments, the cultural practices that have guided Western scientific epistemologies and pedagogies have contributed to trends that hinder progress in STEM fields and education. Western science has been seen as a universal and objective epistemology for centuries, despite its cultural origins (Herman, 2016; Nisbett et al., 2001). This assumption still permeates Western education today, perpetuating a system of inequity that disadvantages learners with different epistemological orientations. Simultaneously, the Western cultural traditions prominent in scientific institutions create additional barriers for people from low-income, rural, ethnic minority and other underrepresented backgrounds in STEM fields. These practices are self-reinforcing, creating a system that effectively filters out diversity and prevents systemic change, because those with diverse perspectives rarely occupy positions of institutional power that govern the system itself.

Critical thinking, creativity, and multicultural literacy are among the 21st Century Skills identified for student success (NCREL & Metiri Group, 2003), yet culturally specific analytic thinking is still the primary pedagogical framework for STEM subjects in K-12 education today. To our knowledge, there is no mainstream curricula devoted to critical reflection on epistemological orientations in STEM. James Banks, in his work on reform for multicultural education (1989, 1991, 2001), described a multicultural model of education as one in which

> "Students study historical, social, artistic, and literary events and concepts from several ethnic and cultural perspectives. Mainstream perspectives constitute one group among several, all of which are equally valid and valuable for educational purposes" (Banks, 1991, Ngai 2004).

Current practices more closely resemble what Banks deemed a "Mainstream Centric" model, or a "Cultural-Additive" model, where other cultural and ethnic perspectives are included in the curricula only to the point that they can conform to the mainstream epistemological framework. For these reasons, multicultural literacy is not being advanced in STEM education. Multicultural education requires that all students, not just those from minority backgrounds, think critically about their own culturally mediated experiences, frameworks, knowledge, and understandings (Ngai, 2004).

Existing research on holistic thinking and pedagogical approaches are largely concerned with understanding the role of culture on cognition and worldview, and how to better serve students of holistic epistemological orientations. Research on curricular interventions for teaching students from analytic epistemological backgrounds a holistic framework is limited if not entirely absent in STEM education. This paper assesses a pedagogical methodology for teaching holistic environmental thinking with targeted curricular interventions.

2. Conceptual Framework

Using a design-based methodology that included collaboration with Washington State Tribal scholars and non-Tribal educators, we were able to assess the use of different pedagogical interventions over a period of three years in a university classroom. Design-based research (DBR) originated out of Ann L. Brown's seminal paper on Design Experiments and represents a

holistic approach where educational research is innovated, assessed and improved through multiple iterations in a formal classroom setting (Brown, 1992; Anderson & Shattuck, 2012).

DBR was selected as a framework for our research because to our knowledge, a model for teaching holistic environmental thinking for students with analytic epistemological orientations has not been developed previously. As such, our curricular tools had to be carefully developed, curated, and assessed to determine their usefulness in a dynamic classroom environment. DBR emphasizes collaboration between researchers and educators (Anderson & Shattuck, 2012), and our desire to develop a multicultural framework for K-12 and college classrooms and emphasis on Indigenous pedagogies necessitated collaboration with partners beyond our own educational unit at the University of Washington (UW). DBR is an ideal framework for studies like ours that focus on piloting new educational methods but has received some criticism given due to the diversity of experimental methods employed, which creates challenges in evaluating outcomes (Anderson & Shattuck, 2012; Collins et al., 2004). For these reasons, we followed Design-Based Research guidelines and recommendations developed by Collins et al. (2004) to produce methodologically robust work.

Our framework for identifying holistic thinking was informed by a review of the literature on Indigenous Ways of Knowing, as well as Nisbett's 2001 model for holistic and analytic thinking (Nisbett et al., 2001). While Nisbett's model was developed primarily based on research with East Asian populations, we feel that it can safely be extended to include the epistemological worldviews of Indigenous populations. Our justification for this application is that Indigenous cultures tend to be more collectivist than individualist, meeting the criteria described in Nisbett's model, and further because ample research supports the finding that Indigenous epistemologies are holistic in nature, corresponding to the holistic cognition and worldview described in

Nisbett's model. Work by Choi et al. (2007) also informed our identification of holistic character in student products.

Indigenous pedagogies were a central component of our approach to teaching holistic thinking about the environment. These were informed by literature on Indigenous education and Ways of Knowing, as well as by Tribal educators on our own teaching team. Storytelling is an important tool used by many Indigenous communities to teach values and practices about the environment and played a large part in our curricular design.

3. Methods

3.1 Goals and Elements of Design

This course was designed as a pilot platform to test different curricular interventions and their ability to teach students holistic environmental thinking in a classroom environment. The class was taught during winter quarter for three years: 2019, 2020, and 2021. Our primary objective was to develop a framework and supplemental tools for educators in K-12 and college classrooms that would aid them in developing multicultural environmental science education spaces that allow students to think critically about the conventional analytic framework utilized in Western science and to learn holistic environmental thought as an alternative but equally valid approach with its own benefits.

Our goals can be summarized as follows:

- Develop and assess pedagogical methods and supplemental tools for teaching holistic environmental thinking through an iterative process.

- Identify the extent to which tools and methods were successful in helping students think holistically through strategic assessment of student work, post-course surveys, and direct observation of the classroom; and
- Develop a set of recommendations for further testing and implementation of a framework for teaching holistic environmental thought.

Design elements of this project included:

- A multicultural team of educators, researchers, and Washington State Tribal members that helped to design and inform our pedagogical methods, course configuration, and supplemental tools utilized in our interventions.
- Guest speakers from both analytic and holistic traditions to help students gain an in depth understanding of how the perspectives differ and how they impact education, as well as environmental management.
- An emphasis on Indigenous epistemologies and how they impact environmental management.
- An emphasis on Indigenous pedagogies, especially storytelling.
- Iteration that allowed us to refine course elements.
- Testing of supplemental tools and activities
- Both in person and online learning spaces (the latter arose as a result of the COVID-19 global pandemic)

3.2 Design Team/Collaborative Partnership

Collaboration with a diverse group of educators was vital to this project and included Washington state Tribal members, UW faculty, graduate students, and both Tribal and non-Tribal educators. We worked closely with these members in planning and adapting the course and the interventions we studied throughout the design process, and they were also part of the instructional team throughout the courses, serving as guest speakers and mentors for the students enrolled in our course.

Prior to the beginning of each quarter, the teaching team met (in person during 2019 and 2020 and virtually in 2021) to develop the course content and interventions and create the syllabus for the class. Interventions were selected through existing research by other scholars, research, and experiences of members of the team, and after Phase 1, success during prior Phases of the course.

During the course itself, team members met regularly both during and outside of the class to provide feedback and discuss any necessary changes to the pedagogical tools and approaches.

Core members of our team are listed in alphabetical order in appendix A.

3.3 Setting

ESRM 490/SEFS 590 is taught at the University of Washington by Dr. Kristiina Vogt, is situated in the School of Environmental and Forest Sciences within the College of the Environment. The University of Washington is an R1 public research university located in Seattle Washington. The course was available for upper-level undergraduate students and graduate students of any discipline. The course was advertised via fliers, word of mouth, and through courses in the

School of Environmental and Forest Sciences. Demographic information from 2019 showed that the student population at the University of Washington is “40.3% White, 21.3% Asian, 7.99% Hispanic or Latino, 6.42% Two or More Races, 2.93% Black or African American, 0.414% American Indian or Alaska Native, and 0.334% Native Hawaiian or Other Pacific Islanders” (DataUSA). Courses for 2019 and 2020 ran for one hour, two times a week. In 2021 the course was online due to the COVID-19 pandemic.

3.4 Course Structure

Phase 1 began in winter quarter of 2019 and was ten weeks in length. Sixteen students were enrolled in the course. Class was held once a week for two hours.

The goal for ESRM 490/SEFS 590 during Phase 1 was to provide an environment where a multi-disciplinary group of UW students could learn to tell contemporary stories about environmental problems that have persisted for decades. The challenge students faced was to script digital stories that balanced conservation, the environment, health, food security, and economics while promoting environmental and social justice. Four class groups learned to apply a holistic knowledge forming process through an Indigenous epistemological lens and employed a council-based decision framework to communicate and engage on complex multi-dimensional environmental problems. Each group was guided and facilitated by the teaching team, consisting of Tribal leaders, systems-based storytelling experts, ecosystem ecologists, DEI specialists, and information and communication technologists.

Phase 2 began in winter quarter of 2020 and was ten weeks in length. Nine Students were enrolled in the course this quarter. The course took place twice a week for one hour, which was a

change from the Phase 1 schedule. This course was impacted by the COVID-19 global health pandemic, and the last few weeks of the course were conducted online. Two graduate students from the School of Environmental and Forest Sciences (Alexa Schreier and Samantha De Abreu) were added to the teaching team as co-teachers during this quarter, while Maia Williams and Maria Blancas departed.

Two new interventions were tested this quarter: the addition of a stakeholder debate activity to encourage students to think about tradeoffs in environmental decision making, and the addition of a K-12 curricula portfolio, to get students to think about educational outreach and specifically look at how they could teach their environmental issue in a K-12 setting while meeting Washington state education standards.

Wildland fire was employed as a major theme this quarter, given its role as a primary disturbance in many Washington state forests, and the changes in fire regimes and fire seasons that have occurred over the past several years as a result of climate change. Fire is also a useful example for illustrating Western and Indigenous approaches to land management, given that Tribal and non-Tribal agencies often manage fires that cross boundaries in the Northwestern United States. Tribal land managers, and managers and scientists working with state and federal agencies were brought in as speakers to juxtapose Tribal vs. non-Tribal management approaches, decision making processes, and priorities in fire mitigation and management.

Phase 3 began in winter quarter of 2021 and was ten weeks in length. Six students were enrolled this quarter. This course was impacted by the COVID-19 global health pandemic and was conducted entirely as an online course, with no synchronous meetings. The University of Washington did not have in-person courses during Winter of 2021. Synchronous meetings were not selected for the course to make the course equitable for students with personal challenges.

Due to the asynchronous environment and the limited number of students enrolled in the course, students worked individually during Phase 3.

This quarter, activities were carefully selected to meet the constraints of a virtual setting, while still advancing the goal of teaching students to form environmental knowledge holistically.

Learning goals for the Phases were constructed based on overarching epistemological targets (i.e., differentiate between linear and holistic orientations, frame a problem using a holistic lens) and task-based targets (i.e., develop a narrative, produce a video, collaborate with others). These are available in Appendix B.

3.5 Interventions

Interventions tested were developed by the teaching team and were either continued or discontinued during the Phases based upon their ability to engage students while meeting the learning goals identified in the syllabus for each Phase.

3.5.1 Oral Presentations

Members of the teaching team as well as additional invited speakers gave presentations to aid in student understanding of course topics. The presenters were selected based upon their respective areas of expertise. Some of these discussions included environmental issues, Indigenous perspectives on the environment and holistic environmental thinking, and Indigenous storytelling. These discussions set the stage for students to utilize a holistic approach in their stories. Speakers and members of the teaching team also gave presentations to help students understand how to develop storyboards and produce digital story products for their final project.

During Phases 1 and 2, students were able to interact more closely with guest speakers and the teaching team, getting feedback during class sessions. In Phase 3, presentations were pre-recorded due to the online learning environment. During Phase 2, an extra emphasis on guest speakers with different stakeholder perspectives was utilized to help students juxtapose analytic and holistic thinking styles, and tradeoffs in environmental decision-making.

The schedule for the courses including the arrangement of speakers was decided in collaboration with the teaching team (Appendix C).

3.5.2 Guided Inquiry

Targeted questions were provided in the syllabus for each topic to guide student inquiry and critical thinking about the topics at hand, as well as framing the topics holistically.

Questions for Phase 1 included the examples below:

Using the marmot example, does knowledge of the natural history of a species, and the ecosystem ecology of their habitat, provide sufficient information to mitigate climate change impacts on a species?
Water development, and all the associated resources linked to water, is a diverse and multi-stakeholder problem where symptoms are temporally and spatially disconnected from one another. Is a holistic approach to forming knowledge and trade-off decisions needed to assess the multi-dimensional formulation of priority access to a diminishing fresh water resource?
How do Indigenous approaches to conservation support maintaining viable wildlife populations across the landscape during seasonal shifts or other abnormal climatic conditions?
Do farmer worker communities maintain credible knowledge of health mitigation strategies that allow them to adapt to climate change impacts that could be the basis of preventative health plans?

Table 2.1 Phase 1 Questions from 2019 Syllabus

Example questions from Phase 2:

What protocols and guidelines are needed to incorporate Indigenous knowledge systems into educational programs?
What, if any, science knowledge or native science was used to support the removal of the Elwha Dam?
What is the potential for Colville to use forest management tools to mitigate the impacts of future fires that originate outside the reservation borders?
Who did you trust as the sources of knowledge on the Elwha Dam and what sources of information did you rely on to produce your evidence? [e.g., scientists, elders, resource managers, politicians, etc]

Table 2.2 Phase 2 Questions from 2020 Syllabus

3.5.3 Student Groups

During Phase 1, students were grouped into a council format to learn how to use consensus-based decision-making, something that some environmental stakeholders such as Tribes utilize. They navigated group dynamics both within and between groups, working to understand an environmental problem and develop a holistic digital story on their chosen problem as a group. Students were organized into four groups, and members of the teaching team acted as advisors for the groups. Wendell George spoke in the beginning of the course on how Tribal Councils work, and how Tribal members make decisions in the modern world without sacrificing the Indigenous Way of forming knowledge.

Within each Council, members represented each of the following priority areas identified by Timber Tribes during the IFMAT I (1993) review: environmental protection, health, cultural support, and economics. Each Council collaborated to frame their environmental problem holistically. Each Council was required to elect a Chair who communicated on behalf of the

group. Groups were encouraged to use Zoom to communicate with one another when not in class.

For Phase 2, students were allowed to self-organize into groups, and the Council Framework was no longer used. Members of the teaching team again acted in advisory capacities to the groups throughout the course, but there were no official designations for which group worked with which member of the team, as was present in Phase 1. During Phase 3, groups were not utilized due to the low number of students and the online format.

3.5.4 Holistic and Linear Storyboard Development

Students were tasked with developing a linear scientific storyboard in addition to their initial draft for a holistic storyboard toward their final story product during Phases 1 and 2. This method allowed students to juxtapose Western analytic approaches to storytelling (deemed the linear approach) with Holistic approaches to storytelling by telling the same story two different ways. Guest speakers presented stories and examples of the different approaches. In Phase 2, students used a holistic storyboard rubric (Appendix D) to identify which elements should be incorporated in a holistic story. In Phase 3, this intervention was not utilized

3.5.5 Stakeholder Debate Activity

Lacey Martin, a high school teacher and teaching team member, had developed a debate activity based on the controversy surrounding the removal of the Elwha Dam in Washington State (the dam was removed in 2012) to help her students think critically about environmental decision making and stakeholder perspective in environmental issues (Appendix E). This activity was

adapted for our course during Phase 2, with the goal of helping our students understand trade-offs in environmental decision making, and to consider what information should be included in a holistic story. Students were given a detailed history of the dam, as well as stakeholder cards with actual testimony provided by federal, state, Tribal and private stakeholders from all sides of the debate during hearings about the dam's removal. Students in our course took up the role and perspective of their stakeholder and argued for or against the dam's removal based on their position.

During the activity, the desks were moved into an open circular format with the center of the room empty. The roles were assigned arbitrarily by the teaching team to each student, and a placard was placed on the front of the desk of each student to represent their role. Students then had 2 minutes each to introduce their side, and then other stakeholders could engage in debates with them after everyone had presented. Students were each given a plastic bead necklace, which was thrown in the center ring to "vote" for which stakeholder was the most convincing. Students were provided with chocolate if they were placed in the top 3 positions.

Due to the lack of synchronous meetings during Phase 3, the stakeholder debate activity was explained by Lacey Martin in a pre-recorded video for students to view. Students were not able to directly participate in the activity given the limitations of the digital format.

3.5.6 K-12 Environmental Curricula Portfolio Activity

For the winter 2020 course, the teaching team grew interested in seeing whether telling holistic stories would allow students to think holistically about environmental problems, but also advocate for education and solutions surrounding these problems. For these reasons, we

incorporated an activity where students developed a lesson plan for an environmental topic for any grade they selected, K-12. Students could select their own platform, and some outcomes included a book, a digital story, and a game. To guide students in developing educational curricula, students were provided with supplementary materials on the Washington State standards: OSPI (Office of Superintendent of Public Instruction), STI (Since Time Immemorial, which specifically addresses education on WA state tribes), and WSSLS (Washington State Science and Learning Standards). One class session was dedicated to Karen Matsumoto's introduction of curricula development and the state standards. Karen Matsumoto and Lacey Martin provided guidance and feedback on the state standards, K-12 curricula development and individual student portfolios.

3.5.7 Alternative Framework Theories

Information Worlds

Information worlds mapping (IWM) was introduced by Phil Fawcett during Phase 2. The concept of Information Worlds (IW) is frequently utilized in the realm of Library and Information Sciences and deals with both smaller social systems of information (i.e., family, a sub-culture) called small worlds and larger systems of information at a macro level (i.e., culture, a country) called life worlds (Burnett & Jaeger, 2008).

IWM was originally developed as a participatory interview technique for healthcare settings, but its use has been expanded to include other qualitative interview settings in which participants develop maps of their own information worlds about systems in their lives (for example social

interactions) pictorially (and using written symbols and words) and identify the important elements and connections in the system at hand (Greyson et al., 2017).

During Phase 3, students were introduced to the concept of IW and IWM through a lecture by Phil Fawcett. They were then required to develop their own information world about their environmental problem to identify vital information as well as connections in the system. This helped students to determine which information should be utilized in the final product, allowing them to exclude extraneous information, while extracting connections that might otherwise be less apparent.

Swiss Cheese Model

During Phase 3, Kristiina Vogt introduced the Swiss Cheese Model (SCM) developed by James Reason (2000) to the class. This model was developed by Reason identify how errors and large-scale accidents can occur in complex systems as the result of latent conditions that create "holes" in the barriers, safeguards and defenses designed to keep systems operating well.

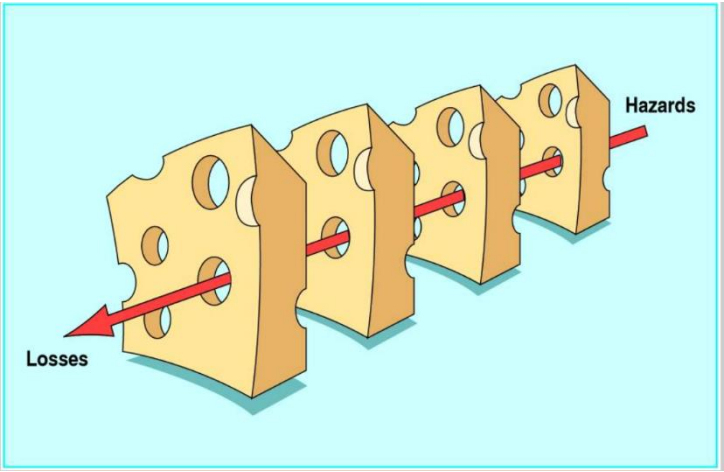

Figure 2.1 The Swiss Cheese Model of how defenses, barriers, and safeguards may be penetrated by an accident trajectory, James Reason (2000)

While the SCM was originally developed to reflect conditions in work environments that lead to workplace disasters or design flaws in consumer products, parallels between traditional work environments and environmental systems, which are also designed, managed, and maintained by humans, allow us to use the model to understand how environmental problems arise, propagate, and sometimes become disastrous. Design flaws, which are a key component of Reason's model are also present in environmental management plans.

The Swiss Cheese Model was used during this course to illustrate the layers of complex environmental problems, and how each layer or aspect can either reinforce or propagate certain errors and issues within a given environmental system.

3.5.8 Storyboarding and Digital Story Production

Storyboarding was introduced as a tool to help students craft their stories with adequate planning and detail. In Phase 1, student groups were tasked with developing holistic stories on one of four environmental themes.

Students were provided with data and background on their environmental theme by the teaching team via class presentation. Students used priority areas identified by Timber Tribes during the IFMAT I (1993) review to identify areas that need to be included in the storyboard and final video.

Each group produced a storyboard and developed a script of their research theme. Example storyboards and outside resources were provided, including information on how storyboards are used in writing movie scripts, and a rubric designed by Phil Fawcett for his CS 302 course in the iSchool at UW (Appendix D). The deliverables expected were a storyboard and a final video

capable of communicating and engaging multiple stakeholders under a climate justice lens, which was presented during the final week of the course.

The final video for each topic occurred as a public presentation on March 15, 2019 titled "*Decolonizing Our Approaches to Conservation, the Environment, Health and Food Security" :* Digital Storytelling of Holistic Knowledge to Contemporary Environmental Problems.

During Phases 2 and 3, student groups selected their own environmental topic as the focus of the storyboard activity. Students presented their final digital stories to class during the last week of the course in an online format during Phase 2 because the university had shifted to online learning in response to the COVID-19 pandemic. During Phase 2, Phil Fawcett's original storyboard rubric was modified by Samantha De Abreu to incorporate holistic principals identified in Phase 1, and the rubric was presented early in the course to inform student work (Appendix D). During Phase 3, the SCM and IWM exercises were used to help guide students in adding complexity and holistic character to their storyboard. Instead of a final digital story product, students were encouraged to turn their environmental problem and storyboard into an interactive game during Phase 3.

3.5.9 Game Development

In Phase 3, games were chosen as a pedagogical approach due to their interactive nature, and the ability to include the element of "chance" which can impact the outcome of the game at any point. In games, cards or other elements are often selected and indicate events that change gameplay through chance.

The inclusion of chance in games is one of the primary reasons this approach was selected for testing during Phase 3. Chance and change are a key element of Indigenous pedagogies. In Native American stories, the coyote is often used as a "trickster" who shakes up the story or moves it along in some manner, rather than being purely good or bad. The ambiguity and complexity of these stories allows listeners to decipher morals and take away wisdom from the story based upon their own worldview. This approach contrasts with stories of European tradition which frequently have a set moral, linear storyline, and good and bad characters.

The complexity of Indigenous stories reflects the complexity of natural systems, where chance events such as wildfires or floods can suddenly change everything about the environmental area being assessed. As such, we felt that it was vital to consider alternatives to traditional storytelling that would have these dynamic elements and engage learners with different learning styles and epistemological orientations. Student groups used the stories created during the storyboarding and information worlds mapping activities to develop a game about their environmental problem.

Games were aimed at being collaborative in design, with the idea of learning to balance multiple stakeholders and perspectives to "win".

Students conducted usability testing exercises for their games with friends and family members, and refined their products based upon the external feedback. Final game products were assessed qualitatively by the teaching team for their creativity, ability to convey the nuances involved in the environmental problem, engage players, and the holistic elements present.

3.6 Assessment of Learning Outcomes

Assessment of in class activities and student engagement was done through classroom observation by the teaching team. Goals from the syllabus were utilized to identify the efficacy of course elements.

Final digital stories were assessed through feedback from the teaching team. Holistic elements sought in the final products were those identified by Indigenous collaborators as vital to holistic stories, and informed by the work of Nisbett et al. (2001) and Choi et al. (2007):

Attention to the environment in which the problem is situated
Emphasis on interactions within the system and between characters and the system, as well as any additional systems involved
View of the system as changing (story with a cyclical pattern and fluctuations vs. linear elements)
Presence of complexity and potential contradiction vs. narrow prescriptive view of problems
Inclusion of multiple viewpoints and stakeholders

Table 2.3 Holistic Elements Assessed in Storyboards and Final Products

Together, these elements helped us assess student storyboards and products, however after Phase 1, the rubric was modified to incorporate holistic elements directly for student guidance (Appendix D). Storyboards were assessed qualitatively by the rubric designed by Phil Fawcett for his CS 302 course in the iSchool (UW) during Phase 1, and by the rubric designed by Samantha De Abreu during Phase 2 and 3 (Appendix D).

During Phase 3, the online nature of the course made it challenging to assess student engagement and understanding via the usual channels such as classroom observation. As such, assessment relied on instructor feedback regarding the products developed by the students during the course.

Student assessment of the course occurred via a post-course evaluation for all Phases, which provided us with qualitative feedback on engagement in the course and the interventions utilized. Given the small class sizes, quantitative data was not obtained from this Data.

4. Results

4.1 Student Engagement

Student interest and engagement in the course interventions for 2019 and 2020 was assessed through classroom observation and post-course evaluations. Engagement for 2021 was assessed through feedback from the students during the course and evaluations after the course, which did show that the online format impacted engagement during this quarter. Qualitative assessment values range from low to high engagement, where low is not very engaging, low student interest and participation, high is very engaging, high student interest and participation.

A summary by intervention is depicted below:

Intervention	**Classroom Engagement 2019**	**Classroom Engagement 2020**	**Engagement 2021**
Group Format	Low	Moderate	N/A
Guided Questions	Low	Moderate-High	
Guest Lectures	Moderate	High	Moderate*
Stakeholder Activity	N/A	High	Low-moderate*
Alternative Framework Theories	N/A	Moderate	High
K-12 Curricula Development	N/A	Moderate	N/A
Linear/Holistic Storyboarding	Moderate	Moderate	N/A
Storyboarding	High	High	High
Final Product Development	Moderate	High	High

Table 2.4 Assessment of Student Engagement in Intervention Activities

*These activities were carried out digitally, impacting student experience.

4.2 Interventions and Student Learning Outcomes

The success of the interventions and curricular framework in helping students develop the ability to think holistically about environmental problems was assessed qualitatively through feedback from student evaluations, classroom observation, and analysis of the final products developed during the courses. Assessment of the development of holistic environmental thinking in our students was based upon both student understanding as well as ability to communicate the concepts in their work.

Student evaluation results are summarized below (original evaluations are confidential):

Question	Phase 1 Responses	Phase 2 Responses	Phase 3 Responses
Was this class intellectually Stimulating?	Yes 8/8	Yes 4/5 No – easy 1/5	Yes 3/3
What aspects contributed most to your learning?	Discussions, In class feedback 7/8 Projects and Storyboarding 2/8	Debates/guest lectures 4/5	Lectures, feedback on game, board game development process
What aspects detracted from your learning?	Course organization, technical aspects of digital story project, need for more speakers, discussions	Tech issues 2/4, none 1/4, not enough class time 1/4	Online format
What suggestions do you have for improvement?	More class time, more material	More lectures, more time, less projects. Mention of groupwork issues	More peer to peer interaction, online issues were mentioned in 2/3 responses.

Table 2.5 Summarized Results from Student Evaluations

A Summary table of interventions used in each Phase can be seen below:

Phase 1	Phase 2	Phase 3
Storyboarding	Storyboarding	Storyboarding
Use of Council Format	Group Format	Individual Work
Holistic/Linear Story Development	Holistic/Linear Story Development	**X**
Tribal Guest Speakers, presentations by teaching team.	Tribal Guest Speakers, K-12 educators, land managers and teaching team	Pre-recorded speaking lectures by Tribal guest speakers and members of the teaching team.
Story Elements Provided by *Instructors*	Story Elements Chosen by Student Groups	Story Elements Chosen by Student Groups
X	K-12 Environmental Curricula Portfolio Development	**X**
X	Stakeholder debate activity	Stakeholder debate activity presented but not performed
X	Brief intro to information worlds	Use of Swiss Cheese Model and information worlds mapping activity
Digital Story as Final Storytelling product	Digital Story or other Digital Product as Final Storytelling Product	Game Development as final Storytelling Product

Table 2.6 Interventions by Phase for ESRM 490/SEFS 590

Digital video examples for 2019 and 2020 can be viewed at the following link: Videos: Environmental Issues — Holistic Learning Collaborative (squarespace.com).

5. Discussion

5.1 Interventions

Presentations by a diverse group of speakers including contributions from local Indigenous educators, scholars and leaders contributed greatly to student engagement and understanding of course activities. Storyboarding, story development and game development allowed students to situate their own environmental problem in a framework that required them to incorporate holistic elements such as change, complexity, interactions, and attention to the setting of the

problem. Additional supports including guided inquiry, alternative framework theories, and the stakeholder debate activity were successful in helping students think critically about epistemological orientations and develop an understanding of holistic knowledge formation which they demonstrated in their final projects.

During Phase 1, the involvement of an Indigenous member of the teaching team or someone with detailed subject matter background on an environmental problem was the greatest predictor for which groups were able to develop holistic stories for their storyboards and final product. The council format did not help students to develop an understanding of holistic decision making and were eliminated after this Phase. Problems included students failing to understand their role in the council and requiring excessive oversight and intervention from the teaching team. Despite providing data and background on environmental problems and Native American storytelling, students were largely unable to produce stories that displayed holistic elements. Students also struggled to identify which information was important for the system in their final stories. These challenges helped us to realize that additional curricular tools and interventions were needed for Phase 2. Storyboards and technical training for digital story development helped students to develop high quality videos, and as such these elements were retained in the next phase.

Students had greater success in developing holistic stories during Phase 2 as compared to Phase 1. The improvement in student ability to understand and utilize a holistic lens for Phase 2 was attributed to two primary sources:

1) An increased emphasis during Phase 2 on Indigenous and non-Tribal educators who not only gave presentations but provided more direct feedback and guidance for student work; and
2) The addition of more engaging tools and activities during the course.

For Phase 2, some tools and activities were found to be more successful than others:

Holistic/linear storyboard production and juxtaposing Western land management practices with Tribal land management practices increased student understanding of stakeholder engagement and epistemological orientations but was discontinued in the virtual setting of the 3rd phase.

The curricula portfolio exercise was challenging for students, given their limited experience as educators. While it served as a useful exercise that showed students could develop a host of products to engage others on environmental topics, this activity was eliminated going into the 3rd phase.

The stakeholder debate was very engaging for students and was popular as an activity, allowing students to consider tradeoffs in environmental management, and the materials were included in Phase 3 for students to read but was not carried out as an activity due to the virtual setting.

During phase 2, Information Worlds Mapping was briefly introduced. Finding that it allowed students to conceptualize the holistic connections in complex environmental systems, this was added to Phase 3, along with the Swiss Cheese model, to help visualize environmental complexity and identify what is important for their environmental system.

During Phase 3, the inclusion of the alternative framework theories helped students to develop a nuanced and holistic view of their environmental problem, which was evident at the storyboard stage. Game development was the greatest success of Phase, 3 because it was not only one of the most engaging tools tested during the 3 Phases of the course, but it allowed students to think critically about environmental elements in a dynamic, changing system. Students in Phase 3 demonstrated a more holistic orientation in their final products when compared to Phases 1 and 2, however it is not entirely possible to fairly assess the benefit of using the game as a final

project over the use of a digital story as a final project because other differences in class structure such as the transition to online learning in Phase 3, added additional confounding factors.

5.2 Student Experiences

Post-course surveys from students were not analyzed quantitatively, due to the small class sizes and inconsistent participation in the surveys, however qualitative information can be gleaned from the surveys. Some excerpts from the evaluations that discussed student experiences of the interventions and the learning process include the following:

2019:

> "As always, Prof. Vogt is full of new surprises, ideas, approaches, and ways of doing things. This course--premised almost entirely on changing our approach to knowledge itself--was no exception. While the case studies were easy enough to study from for those who have experience in upper- division coursework, the project format placed great emphasis on bringing this information together into a result. Learning to work collaboratively, take in critique, and democratically make decisions towards solutions was absolutely invaluable. Breaking down our run-of-the-mill approaches step-by-step, changing them, and eventually presenting the results put a whole new spin on the seminar format that I would love to see more of in an undergraduate environment"

"Class would have benefited substantially from more devoted time to speak with our respective experts and having more readings/material on our case studies through Canvas to direct independent research"

2020:

"I really enjoyed the class projects and contributions of many different educators, so I wouldn't suggest any changes there. I would potentially suggest a more developed activity/survey early on to pick groups, as I unfortunately had to be placed randomly with a group that I did not have much in common with"

"I love the step-by-step process to make the final video. Every project before the final one give me opportunities to further think about how to revise the final one to a better condition"

2021:

"I liked that the process of designing a board game was divided into sections, which really helped me not get overwhelmed with our assignments. Being able to focus on one part of the process of designing a game each week really helped build a solid foundation of knowledge for me to produce a game"

> “This is a great class, that should be offered in the future. However, it was a bit frustrating to work on a boardgame and not being able to play it in person with the professor and classmates, that would have make the experience more nurturing”

> “This class was very intellectually stimulating. It required me to think about environmental communication and education in a way that I hadn't before, and to really try to balance the use of creativity with science. It also required a more holistic approach to environmental thinking, which really challenged me to think about the bigger picture”

These responses indicate the success of certain interventions such as guest speakers and the board game development project, while also indicating different issues present during the Phases, for example, challenges with the online learning environment that resulted from the COVID-19 pandemic and impacted half of Phase 2, and all of Phase 3. Student evaluations were in line with qualitative assessments by the teaching team of the areas of success and improvement in the course. During Phases 1 and 2, the evaluations helped to guide development of future phases.

5.3 Recommendations for Future Research and Implementation

This research has shown promise that students from diverse epistemological backgrounds can learn new ways of forming knowledge. Future research using these interventions should be conducted for in-person and online learning environments, given the likelihood that a larger portion of learning experiences may be online in the future. Research on games should continue to be pursued as an opportunity to engage and educate youth in a fun and memorable way. Quantitative statistics may be achieved by using larger class sizes and ensuring student

participation in surveys. During this project, students benefitted most from engaging hands-on activities and tools that allowed them to think about their environmental problem from different perspectives, as well as lessons delivered by Indigenous educators who were familiar with holistic environmental principals and storytelling. While our interventions focused on Washington state Tribes, implementation of the interventions should include regional tailoring to reflect the rich diversity of Tribal cultures.

Indigenous educators and guest speakers contributed greatly to our course and the ability of students to understand holistic storytelling and holistic knowledge formation. While there have been shifts toward including Indigenous knowledge in the classroom (for example, the STI in Washington State), representation of Indigenous pedagogies and epistemologies in STEM are still lacking.

Indigenous educators globally have been involved in innovative community outreach projects and education projects, where they have worked to educate Indigenous and non-Indigenous youth on curricula, culture, and the environment. Many schools use materials designed by Indigenous educators in their lessons, however, lasting partnerships with local tribes at the district or school level would more closely align with the recommendations that came out of a 2010 conference on integrating Indigenous Knowledge and Western Science (Mason et al., 2012).

Seven elders from the Kootenai and Salish-Pend d' Oreille Culture Committees along with twenty native and non-native land managers, scientists and academics established guidelines for knowledge sharing, which included the following: development of a national program tailored at the regional level, collaborative and enduring interpersonal relationships between members of the tribe, agencies and educational institutions, and an emphasis on cross-cultural education,

including partnerships between Tribal colleges and universities, and an emphasis on recruiting and retaining Indigenous people in academia (Mason et al., 2012). Collaboration between Tribal and non-Tribal educators has the ability to move STEM education toward social and environmental justice through the inclusion of historically excluded voices and perspectives. Inclusion of diverse perspectives in STEM education may help turn the tide of the low participation of minority and underrepresented groups in STEM disciplines, which has the capacity to create a more ideologically diverse, robust STEM community overall.

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Appendix A: Teaching Team Members

Samantha De Abreu *PhC, School of Environmental and Forest Sciences (SEFS), University of Washington (UW)*
Wendell George *Confederated Tribes of the Colville; former Councilman, Author of "Go-La'-ka Wa-Wal-sh (Raven Speaks)", "Coyote Finishes the People", "Last Chief Standing"*
Phil Fawcett *PhD, Guest Faculty Member, iSchool, UW; Contributing Author: "The Medicine Wheel: Environmental decision-making process of Indigenous peoples"*
Michael Marchand *PhD, Confederated Tribes of the Colville; former Chair and Council Member; Lead Author: "River of Life: Sustainability Practices of Native Americans and Indigenous Peoples", "The Medicine Wheel: Environmental decision-making process of Indigenous peoples"*
Lacey Martin *High School Teacher, Granger High School*
Karen Matsumoto *Climate Change & Environmental Science Educator, Suquamish Tribe*
Alexa Schreier *M.S., SEFS and Evans School, UW; Co-Author: "The Medicine Wheel: Environmental decision-making process of Indigenous peoples"*
Michael Tulee *PhD, Executive Director, United Indians of all Tribes Foundation, Yakama Nation member; Contributing Author: "The Medicine Wheel: Environmental decision-making process of Indigenous peoples"*
Daniel Vogt *PhD, Professor, SEFS, UW; Co-Author: "River of Life: Sustainability Practices of Native Americans and Indigenous Peoples", "The Medicine Wheel: Environmental decision-making process of Indigenous peoples"*
Kristiina Vogt *PhD, Professor, SEFS, UW; Honorary Masters in Art, Yale Co-Author: "River of Life: Sustainability Practices of Native Americans and Indigenous Peoples", "The Medicine Wheel: Environmental decision-making process of Indigenous peoples"*

Table A.1 Core Teaching Team Members for ESRM 490/SEFS 590

Appendix B: Learning Goals by Phase

1. *Learn to recognize the differences between the scientific method approach and a holistic approach to tell a story of a complex environmental problem, e.g., linear versus a journey that reflects a holistic knowledge forming process.*
2. *Learn a framework to tell a holistic story based on knowledge that includes environmental protection, nature health, cultural support, and economics for one environmental problem being impacted by climate change.*
3. *Learn to write a narrative using non-linear science knowledge forming process, e.g., the endpoints not predefined.*
4. *Learn to collaborate with Tribal leaders, Storytellers, Systems Ecologists, and Communication/Technology experts to reframe the identified problem within the holistic knowledge context – context being complex, multi-spatial and temporal problems.*
5. *Work as a team to develop a story narrative and produce a video that communicates that a story using art/imagery and music.*
6. *Learn the process to design and shoot short videos of several stories using a cloud-based video editing tool.*

Table B.1 Phase 1 Learning Goals from 2019 Syllabus

1. *Develop an understanding of holistic learning processes and perspectives.*
2. *Acquire and apply knowledge and skills about translating an environmental issue into a memorable and impactful story.*
3. *Collaborate with classmates to produce a digital communication deliverable (e.g., video, flipbook, podcast, etc.) to display a holistic understanding of a local environmental issue.*
4. *Develop an understanding of the importance and value of effectively communicating complex environmental issues using the art of storytelling.*
5. *Develop an understanding of the role of holistic place-based storytelling for K-12 students and how curricula and methods for environmental storytelling can be adapted to meet state teaching standards focused on educating students on Indigenous knowledge.*

Table B.2 Phase 2 Learning Goals from 2020 Syllabus

1. *Learn to identify who and what problems should be part of your environmental story*
2. *Learn what does it mean to tell an Indigenous holistic story with wisdom instead of information that provides you no knowledge*
3. *Learn to identify how environmental stories can balance information with gaming elements to be interesting*
4. *Learn how to take an environmental problem and produce a holistic storyboard using the Swiss Cheese model*
5. *Learn how to test your storyboard and script to get feedback on your storyboard*

Table B.3 Phase 3 Learning Goals from 2021 Syllabus

Appendix C: Course Speaking Schedules

Date	Speaker	Topic
1/11/19	Kristiina Vogt	Class Goals, Holistic and Linear Thinking
	Wendell George	Tribal Councils, How Tribal members produce knowledge, make decisions, and adapt to Western institutions
	Terryl Ross (Asst. Dean of DEI, College of the Environment, UW)	Video and film production, introduction to WeVideo®
	Phil Fawcett	Elements of a storyboard
1/18/19	Mike Marchand	Elements, structure, and flow of Native American creation stories; Native American wisdom stories by Jay Silverheels
	Phil Fawcett	Elements of stories
	Maia Williams (SEFS Graduate Student, UW)	Information provided for holistic story selection, Diverse sources of knowledge and information
1/25/19	Isabel Carrera Zamanillo	Structure of Stories; PLOS Blogs Science; Storytelling in Science Education
	Alishia Orloff	Characteristics of stories from Native Storytellers
	Mike Marchand	Information for story topics
	Maria Blancas (SEFS Graduate Student, UW)	Information for story topics
	Victoria Buschman (SEFS Graduate Student, UW)	Information for story topics
	Angel Clark (UW student)	Water Quality
2/1/19	Elliot Stevens (Assistant Research Commons Librarian, UW)	Digital Story Production: Using WeVideo®, copyright and fair use, Creative Commons media
2/8/19	Phil Fawcett	Designing a Storyboard and Engaging your Viewer
	Isabel Carrera Zamanillo	Designing a Storyboard
	Teaching Team/Class Discussion	Review and discuss storyboards produced by student groups
2/15/19	Teaching Team/Class Discussion	Discuss flow of revised holistic storyboards
	Isabel Carrera Zamanillo	Structure of a storyboard
	Phil Fawcett	Rubric for Storyboard evaluation
2/22/19	Teaching Team/Class Discussion	Native American Perspective in storytelling
	Wendell George	How to tell a story from a Native perspective
	Jordan Bender (UW student)	What is the hook in games
3/8/19	Teaching Team/Class Discussion	Viewing and discussing final videos

Table C.1 2019 Speaking Schedule

Date	Speaker	Topic
1/7/20	Kristiina Vogt	Class Goals, Holistic and Linear Thinking
	Samantha De Abreu	Class Goals, Holistic and Linear Thinking
	Alexa Schreier	Class Goals, Holistic and Linear Thinking
1/9/20	Phil Fawcett	Storyboard introduction: Components and building of storyboards. Storyboard evaluation rubric introduction.
1/14/20	Mike Tulee	Kinesthetic and Spatial learning styles and Indigenous learners
	Kristiina Vogt	How storytelling bridges different learning styles
1/16/20	Karen Matsumoto	Indigenous Knowledge systems and Western Science approaches to knowledge formation about nature, incorporating Indigenous Knowledge into K-12 education
1/21/20	Elliot Stevens	Digital Story Production: Using WeVideo®, copyright and fair use, Creative Commons media
1/23/20	Wendell George	What makes a Tribal story different from Western European stories; animal people in Tribal stories
	Phil Fawcett	Advanced storyboarding, information worlds mapping
1/28/20	Lacey Martin (Granger HS)	Holistic understanding of the Elwha Dam's history and the controversy surrounding its removal
1/30/20	Teaching Team/Class Activity	Elwah Dam debate activity
2/4/20	Ernesto Alvarado (Research Associate Professor, SEFS, UW)	Wildfire Management, USFS and Tribal management in Washington State
2/6/20	Mike Marchand	Wildland fires and land management by Confederated Tribes of the Colville Reservation
2/11/20	Steve Rigdon (General Manager, Yakama Forest Products)	Yakama Nation Forest management practices and wildland fire
	Ashley Blazina (Natural Resources Specialist at Forest Health Division, WA dept. of Natural Resources)	DNR community engagement and wildland fire mitigation
2/13/20	Samantha De Abreu	Discuss the state of wildfire management in WA, and what it would look like if a holistic story were to be developed on wildfire in WA. Discuss the viewpoints and controversies between stakeholders involved in wildfire management
2/18/20 2/20/20	Mike Marchand Phil Fawcett Kristiina Vogt Samantha De Abreu Alexa Schreier	Review storyboard drafts and provide feedback
3/3/20 3/5/20	Karen Matsumoto Lacey Martin	Provide feedback for K-12 Curricula Portfolio presentation

Table C.2 2020 Speaking Schedule

Date	Speaker	Topic
1/5/21	Kristiina Vogt (Panopto)	Class Goals, Holistic Storytelling for Environmental literacy, and Justice
1/7/21	Mike Marchand (Panopto)	Native American Coyote Stories, and coyotes as tricksters
1/12/21	Mike Tulee (Panopto)	Kinesthetic vs. Spatial Learning process in storytelling and games, communicating with and engaging Tribal youth
1/14/21	Lacey Martin (Panopto)	Introduction to the Elwah Dam Controversy
1/19/21	Phil Fawcett	Designing a Storyboard and Engaging your Viewer
1/26/21	Phil Fawcett	Information world mapping
2/2/21	Phil Fawcett	Game Elements and how to make your storyboard into an interesting environmental story
2/9/21	Kristiina Vogt Jenn Engelke (Grad Student, College of Built Environments, UW)	How to produce complex stories with multiple storyboards using the Swiss Cheese Model; Chance and game elements
2/23/21	Phil Fawcett	Designing and executing a usability test for your storyboard or game

Table C.3 2021 Virtual Presentation Schedule

Appendix D: Storyboard Rubrics

		Excellent	OK - needs some improvement	Weak – Needs significant improvement across most areas of the Story
1.	**Storyboard describes or shows the objective, purpose, and scope**	An introduction succinctly describes the topic with a tone that fits the topic and audience. The reader can quickly grasp the main idea of the project. The purpose and scope are clear.	Document has an introduction, but lacks clarity. Document has most of the elements of an introduction, but not all.	Storyboard or design document starts without an adequate introduction.
2.	**Storyboard describes or shows reader who the intended audience is**	There's a clear depiction of a specific intended audience.	The description of the audience is too vague or general.	There is no description of the audience.
3.	**Storyboard uses media elements appropriately to enhance and enable the key message of each Storyboard frame.**	Multimedia elements, such as music, images, video, animation, voiceover, sound effects, etc., are clearly shown and described and used in the Storyboard.	Some media elements are shown in the Storyboard but don't appear well thought out.	The Storyboard does not describe media elements but could benefit from a few with select pieces of content.
4.	**The Storyboard has a logical organization, effective structure, key messages, and provides guides/visual cues for the reader.**	Storyboard has a strong sense of direction. There is a definite beginning, middle and end. Story arcs and turning points are well defined.	Story and central themes are evident, but the beginning, middle and end are not completely clear. Story arcs are not obvious.	Storyboard does not have enough substance or is not developed. The structure is not clear. Story arcs or turning points are not described.
5.	**The Storyboard is succinct and clear**	Reader can easily and quickly grasp concepts, flow, and the direction of the story.	The Storyboard is mostly clear and succinct but has missing elements or is somewhat vague.	The Storyboard needs to be adequately described or needs revision for clarity.
6.	**The Storyboard depicts a clear ending**	The design of the story describes a clearly resolved conclusion.	The ending is described, but not as clear as it could be.	Story does not describe how the story ends.
7.	**The Storyboard has few mechanical defects**	Author has revised and proofread the content in the design, and there are few errors with the spelling and grammar. The style is consistent across each Storyboard frame.	The Storyboard has three or more errors or inconsistencies.	There are too many mechanical defects the mar the clarity of the Storyboard.

Table D.1 Storyboard Evaluation Rubric designed by Phil Fawcett for CS 302, Human Computer Interaction

Storyboard Element	Excellent	Satisfactory	Needs Improvement
Storyboard shows or describes the objective, purpose and scope of the story	An introduction draws the reader in and sets the tone. Main themes are clear throughout the storyboard.	There is an introduction, but it is confusing or unclear. Themes and the tone are vague or confusing	There is no introduction, and themes and tone are absent or severely deficient.
The story depicts how each piece of the system works with and interplays with other system elements.	The storyboard explores multiple inextricable system interactions and how those interactions feed into one another	The storyboard depicts one or two system interactions, but misses some other important interactions that should be considered	The storyboard fails to include multiple system elements, or fails to adequately convey the importance and relationship between system element interactions.
The story explores any external systems that interplay with the system at hand, and integrates multiple viewpoints	The storyboard includes multiple varying perspectives on the topic at hand, and includes any external systems interactions that are important	The storyboard depicts some external systems or viewpoints but how this impact the system of interest is unclear or confusing.	The storyboard fails to consider external systems or viewpoints of community or governmental stakeholders.
The storyboard lays out how media/digital tools will be used in each frame to craft and enhance the narrative	Media elements, such as music, images and video are clearly described and add to the story in a meaningful way	Media elements are present but are not well thought out and/or do not add to or compliment the story	Media elements are not present in the storyboard
The intended audience is shown or described in the storyboard	The audience is clearly described in the storyboard	The audience chosen is too vague or general	The audience is not shown or described in the storyboard.
The storyboard is clear, concise and free of major mechanical errors	The storyboard is well organized and shows consistent formatting, with few grammatical and spelling errors	The organization is somewhat confusing and/or there are basic editing errors that need to be resolved	The organization and format are very disorganized, vague or confusing and/or there are abundant editing errors.
The storyboard is logically organized with clear messages and visual/written clues which guide the reader through the story	The story flows well and allows the reader to step into the story world. Clear story arcs and turning points enhance the story.	Central themes are present, but there is some confusion about the direction of the story, or the story is lacking key elements that would enhance the narrative.	The story is not well developed or lacks substance. Story arcs and turning points are absent or unclear

Table D.2 Holistic Storyboard Evaluation Rubric: ESRM 490/SEFS 590

Appendix E: Elwha Dam Stakeholder Debate Activity

Hydroelectric Power has long been touted as a clean alternative source of energy. It produces roughly 70% of the power in the Pacific Northwest. However, hydroelectric is not without its costs. Salmon runs on the major river systems, such as the Columbia River, and on minor rivers, such as the Elwha River in Olympic National Park, have suffered greatly in recent decades, and some of these salmon species are becoming listed as endangered or threatened species. Today, large dams on the Columbia River, owned by the Bonneville Power Administration (BPA) provide the majority of the power for the Pacific Northwest. Yet hundreds of small, privately owned dams are scattered around the region. These are in various states of disrepair, and often only provide enough power to fuel a small community or one or two factories. However, these dams do as much or more damage to the salmon runs in their area than the large dams (BPA dams have extensive programs to help the fish successfully navigate the dams). This lesson is derived from real testimony given to Congress regarding two of these small dams in the pristine Olympic National Park in Washington.

In this Role Playing activity, students will play the role of various stake-holders in the dam removal debate for the Elwha River. Students will build consensus to try to solve the problem. The following Role Cards are available:

Role Card: Steven Fitzpatrick, owner of the licensed Glines Canyon Dam

This Role Card is part of the collection of resources for a Debate Activity: Salmon vs. Dams

Statement of Mr. Steven Fitzpatrick

I have owned the Glines Canyon Dam for 28 years now and we have never come across a problem with relicensure. Our dam has run smoothly throughout the second part of this century and we have provided a valuable resource for the people of Port Angeles. The dams here assure the people that they have a clean drinking water supply which the government has to supply according to the Safe Drinking Water Act of 1974. If the dams were to be dismantled, the government would somehow have to ensure an alternative source of clean drinking water, which may be quite costly.

These dams have also been an integral part of this community by providing power for the Daishowa of America Paper Mill, which is the largest employer in this district. 100% of the power produced here is used locally by that business. If these dams are dismantled, the government will have to come up with an alternative source of energy that is affordable for the people of Port Angeles.

Finally, there are the interests of private investors such as myself. If the dams are to be removed, then the dam owners will to be compensated. This dam is my livelihood and I have been here my whole life. I do not want to see it destroyed.

Role Card: Honorable Al Swift, US Representative from Washington

This Role Card is part of the collection of resources for a Debate Activity: Salmon vs. Dams

Statement of Al Swift:

The eight historic fish runs on the Elwha River have often been described as legendary. Those who can remember a time before the Lower Elwha and Glines Canyon dams were built remind us that massive salmon, some as big as 100 pounds, once moved freely up the river. Tens of thousands of salmon returned one year to find a wall of concrete where a river had once been. Sadly, yet predictably, those legendary runs soon ceased to exist.

Those salmon were more than an ecological wonder. They were an economic resource for the people of Port Angeles. Our goal is to see those runs flourish again. It is unquestionably a worthwhile goal, but getting there means far more than simply contemplating the removal of two dams.

Statement of Honorable Al Swift, Cont'd

There are some interesting legal issues at stake here. These include the treaty of Point-No-Point of 1855 in which the federal government promised local Indians fishing rights on this river. Also included is the issue of whether it is legal for the Federal Energy Resource Council to license a dam in a National Park such as the Glines Canyon Dam. It is certainly illegal now to build a new dam in a national park, so the question is does the Glines Canyon Dam have precedence over the law since it was built before the park was created? At the same time, the Endangered Species Act requires that the federal government look after the interest of species that in danger of becoming extinct. On the Elwha River, there is at least one species of salmon that is borderline and many other species are headed that way. On the other side of the coin, the Safe Drinking Water Act of 1974 requires that the federal government ensure its citizens clean water. If the dams are removed, we will have to find an alternate water source.

If we find that the Glines Canyon Dam is not to be relicensed, then we need to decide who will be responsible for the dam. It cannot be left unoccupied because over time that could lead to a dangerous situation for the people living downstream. If the dams are unlicensed, we need to ensure that some provision is made to dismantle them. Otherwise, the fish will not improve and the Daishowa Corporation will be without power. Therefore, we should not act hastily.

Finally I come to cost. Recent estimates say that the entire package, including dam removal and fish restoration, could cost between $60 and $80 million dollars. This is substantial I admit, but put it into the proper perspective when we look at far larger sums being spent for fish restoration on other rivers in the Northwest.

Role Card: Beatrice Charles, Tribal Elder, Lower Elwha S'Klallam Tribe

This Role Card is part of the collection of resources for a Debate Activity: Salmon vs. Dams

Statement of Beatrice Charles:

I grew up on a farm alongside the riverbanks of the Elwha River. The farm that I grew up on is now the State fish hatchery and the diversion pipe for the ITT Rayonier water runs through it. When the dam was built some 20 years before, I was a young child then. My elder, Sam Almer, used to talk about the places that were the spiritual places for the Klallam people to go to. When the dam was built the water went over this spiritual ground where my ancestors used to go for spiritual guidance and help.

I also heard about the dam when it broke in 1912 and the damage and devastation that it had done to my grandmother's farm. To top it off the Indians weren't notified that there was danger. My late father was around 18 years old and he was out washing his face out on the porch where we used to have our water for washing our faces and so forth and so on, and he heard the big roar. He knew right away what it was. So he told his mother and the rest of the family to run for higher ground.

Statement of Beatrice Charles, Cont'd

I was young at the time that we lived on the farm, but I remember how the fish runs were because our family used to gather on the bank in front of the house and we used to have probably a family conference there because I was a child. I used to run around, but I saw the fish runs. It was just ripples of salmon going up and they were big salmon. I remember. I saw it and I know that it was there. We all felt it was always going to be there that it wasn't going to be depleted but I was wrong.

The dam used to open their gates and a lot of water would come down. Then they would close it up. There were pools of water where the little fish were stranded and when the pools went dry, the fish were dead. That's what happened to the fish.

I feel we should remove the dam because I know the devastation that it had done to my people because I've seen it and I know it.

As the years went by, the fish depleted to the point where it's nothing. Our creator gave us this fish to live on, and it was rich and an abundance of fish. It was given to us and we cherished it and we respected it. We never got more than what we could use. We used it and every bit of it. We didn't waste it.

I feel again I would like to see the dam removed while I'm still alive. I may not see the abundance of fish come back in my lifetime, but I would like to see it come back for my grandchildren, my great grandchildren and for the rest of my people in the following generations to come. It was a gift from our creator; it was our culture and our heritage.

Role Card: Honorable Malcom Wallop US Senator from Wyoming

This Role Card is part of the collection of resources for a Debate Activity: Salmon vs. Dams

Statement of Malcom Wallop:

The bill pending before the committee would expose the Department of the Interior to spending hundreds of millions of taxpayer dollars due to the following: 1. to take over and tear down two privately-owned, operating hydroelectric dams, 2. to restore environmentally the river on which the two dams are located, 3. to make up for the increased cost of cheap power the dams supply to a corporation, and 4. to provide "high quality" water to the city of Port Angeles and others.

A FERC draft environmental impact statement has placed the cost of removal of the two dams and hydroelectric projects at $245 million.

It should also be noted that although the Department would acquire the two dams and the associated hydroelectric projects, removal would still be dependent on the feasibility of actually tearing the dams down. It is entirely possible that the Department would just end up owning and operating these dams and hydroelectric projects for the foreseeable future.

Based on the cost estimates made by FERC, I question the cost-effectiveness of this bill, particularly when the actual costs of dam removal and river restoration could ultimately prove to be far higher than that estimated by FERC. Moreover, there are other costs not included in the FERC cost estimate. For example, the city of Port Angeles has shown that the capital cost of the facilities to provide high quality water is $30 million, plus yearly operational expenses of $2.5 million.

The question is: Do we look before we leap or do we leap before we look?

On a wholly unrelated matter, the bill also requires the Department of the Interior to transfer some land back to the Indian tribes. This is a very significant provision. As stated by the City of Port Angeles: "In a nutshell, Port Angeles would not be Port Angeles without this land." The city also states that it "would be unimaginable for our City to lose control of this land." Unfortunately, this is exactly what the legislation would require.

Role Card: John Hayden, Assistant Secretary for Fish and Wildlife and Parks, Department of the Interior

This Role Card is part of the collection of resources for a Debate Activity: Salmon vs. Dams

Statement of Mr. John Michael Hayden:

The Department of the Interior supports the restoration of the Elwha River ecosystem and fisheries through the development and implementation of a fully cost-shared Elwha River ecosystem and fisheries restoration plan. This will permit the federal government to fulfill trust responsibility to Indian Tribes through the Bureau of Indian Affairs, commitment to preserve the resources of Olympic National Park through the National Park Service, mandate to conserve fish and wildlife resources and habitats through the Fish and Wildlife Service, and obligation to protect living marine resources and endangered marine species through the Department of Commerce's National Marine Fisheries Service.

Olympic National Park is internationally important and is an international Biosphere Reserve and a World Heritage Site. The Elwha River is the largest watershed in Olympic National Park. The Glines Canyon project is located on the Elwha River with Olympic National Park boundaries. The Elwha project is outside the park boundary, about 8 miles downstream of the Glines Canyon Dam. Historically, large runs of anadromous fish, including all five species of Pacific salmon (Chinook, coho, pink, chum, and sockeye), steelhead and cutthroat trout, and Dolly Varden char returned from the ocean to spawn in the Elwha River. The runs of these fish have declined dramatically because the Elwha and Glines Canyon dames on the Elwha River block access to more than 65 miles of 90% of the spawning and rearing habitat formerly used by these fish, and prevent the replenishment of the needed spawning gravel to the habitat still accessible below the lower dam. The upper Elwha River habitat, all of which lies in Olympic National Park, is without salmon and steelhead. Lower Elwha River stocks on spring-run Chinook salmon and pink salmon are at risk of extinction, while Elwha sockeye may already be extinct.

Wildlife populations within the Elwha River Basin and Olympic National Park have also been severely impacted by the loss of anadromous fish which are an important food source. The reestablishment of anadromous fish to their former habitat would greatly benefit at least 22 species of wildlife, including the black bear, river otter, and bald eagle, and would contribute to the recovery of these populations.

Role Card: Hishogi Daishowa, owner of Daishowa of America Paper Mill

This Role Card is part of the collection of resources for a Debate Activity: Salmon vs. Dams

Statement of Mr. Hishogi Daishowa:

I have owned the Port Angeles Pulp Mill since 1987. This pulp mill directly provides employment for 12% of the citizens of Port Angeles and indirectly supports numerous others. At this point 70% of the power for this pulp mill comes from the Elwha River and Glines Canyon Dams. Because of their local situation, these dams provide us power at a much cheaper rate than we would get from the Bonneville Power Administration which is the major energy provider in this area. This enables a small business owner such as myself to be able to be competitive in the larger market. If these dams were to be closed, I would have to start charging higher prices. Higher prices would mean that I would not be as competitive and I would have to lay off some of my employees. I believe that this would have a ripple effect in a community as small as Port Angeles and that it could cause an economic slump. I understand that the dams are inhibiting the migration of anadromous fish species, but we have to get our priorities straight.

In addition, my mill depends on water from the Elwha reservoirs. If these dams are removed the water supply to my mill will be lost.

Role Card: Dennis Gaithard, Consulting Engineer, Summit Technology, Inc.

This Role Card is part of the collection of resources for a Debate Activity: Salmon vs. Dams

Statement of Mr. Dennis R. Gaithard:

Artificial reservoirs on glacial streams trap large amounts of the sediment that the stream system is carrying from the mountains to the seashore. That is what has happened on the Elwha for more than 70 years. The feasibility of removing the dams without causing an uncontrolled release of stored sediments is the most critical issue involved with dam removal. In order to resolve that issue with a high degree of confidence, our engineering team deliberately explored very practical, conservative techniques of dam removal and sediment management. A conservative solution would then provide a backdrop against which to evaluate more innovative alternatives.

Although additional work is needed to specify the details of construction, we have identified reliable, orthodox methods for draining the reservoirs, reconfiguring and stabilizing the trapped sediments, taking down the dams, and protecting water supplies. This can be done without unacceptable environmental consequences and at a lower cost than predicted by the dam owners.

In order to return Elwha River to its natural pre-dam condition, three primary engineering tasks must be carried out.

1. Remove sediment trapped in the dam's reservoirs from the river's path, restore the river channel, and stabilize the removed sediment
2. Remove the dam structures and power generating and transmission equipment, and
3. Protect structures and water supplies downriver from the effects of dam removal

None of the proposed actions is based on speculation or unproven research. In some cases, additional information will need to be gathered to refine the details on construction. However, enough information exists to conclude that the approach is feasible.

Role Card: Jim Chee, S'Klallam tribal elder

This Role Card is part of the collection of resources for a Debate Activity: Salmon vs. Dams

Statement of Jim Chee:

The people of the S'Klallam tribe are here to demand that the government honor their agreement made in the Treaty of Point-no-Point here in the Olympic National Park in 1835. This agreement, made between the American Government and my people, grave our heritage, the land of Olympia, to the American people in exchange for unlimited fishing rights on the Elwha River Dam. This dam restricts the migration of salmon and other fish so that they are dwindling in number. There are now very few fish on the Elwha and my people have no land. They have been treated very badly, but now we see the opportunity to correct this egregious wrong by taking down the Elwha River and Glines Canyon Dams.

After the dams were built, and fishing became difficult, my people began to collect shellfish from the Elwha River Delta, the sandy area where the river meets the sea. However, in recent years, this delta has begun to subside or disappear. Our scientists say that the dams are responsible for this disappearance too. They say that sediment is trapped by the dams so that the beaches are not being replenished. Now the American Government is cheating us out of our right to collect mussels on the coast because they are stealing the sand behind the dams. Once again, removal of those dams is the only course of action that can correct this error.

Our tribe arose from the rocks on the Elwha River. The rocks that gave birth to our people lay alongside the river and our people worshiped at them to thank the great being for giving us our lives and this wonderful land to live in. However, when the American government built the dams on the Elwha, they flooded this holy ground, so that now the S'Klallam people cannot worship at their holy sites. According to our scientist, the water in the dam has now deposited the sand that should be in the delta over the holy site. We want to see it removed completely so that S'Klallam people can once again thank the Great Being.

Appendix F: Glossary of Terms

Analytic Cognition: Viewing the universe as comprised of discrete objects with set properties

Design Based Research (DBR): A method of research concerned with implementing and testing educational interventions in a dynamic classroom setting, where they are methodically refined based on assessment and outcomes.

Epistemological Orientation: Socio-culturally mediated knowledge forming tendancies

Holistic Cognition: Viewing the universe as comprised of interconnected elements and relationships

IFMAT: Indian Forest Management Assessment Team

Indigenous Ways of Knowing/Traditional Ecological Knowledge (IWK): An understanding of the relationship between humans and the environment gained over a period of time and carried out and understood through spiritual and cultural practices and beliefs. A holistic knowledge building process

Information Worlds (IW): Typically used in information sciences to explore interconnections and relationships in a given system.

Information World Mapping (IWM): A method of visualizing the connections in an IW system.

Interventions: Educational tools tested during the classroom experiments

OSPI: Office of Superintendent of Public Instruction

Swiss Cheese Model (SCM): A model originally developed by James Reason for understanding how errors propagate

STI: Since Time Immemorial: Curricula program in Washington State for education on Tribes

WSSLS: Washington State Science and Learning Standards, previously known as the Next Generation Standards.

Chapter 3. Suggestions for Holistic Fire Management

Abstract

Currently, State and Federal agencies in the United States develop science-based strategies to manage wildland fires to minimize forest loss and to reduce fire impacts on communities living near forests. Tribal management of wildland fire uses holistic, community, and values-based management to prioritize goals for management. This management strategy often prioritizes engaging multiple community perspectives. Despite these differences, wildfire often crosses agency boundaries, forcing these different management perspectives into contrast. Tribes may be disadvantaged by the lack of engagement and communication offered by state and federal agencies when addressing wildfire management. Top-down approaches and strict legislative control over state and federal guidelines constrain agencies from working more collaboratively with community stakeholders and other management agencies such as tribes.

1. Introduction

1.1 Wildland Fire Management Policy at the State and Federal Level in the United States: A Brief Background

Institutionalized wildland fire management policy in the United States dates back to the formation of the United States Department of Agriculture Forest Service (USFS) in 1905 and the subsequent policies of fire suppression implemented in 1911 after a series of particularly large fires in 1910 (Pyne, 1982). Prior to 1905, forest reserves were managed by the department of the interior, but the Forest Transfer Act of 1905 shifted management responsibilities to the United States Department of Agriculture (USDA) (Busenberg, 2004). During this time, forest reserves (which would later become the National Forests of today) were expanded rapidly. Due to the increased area of timberland to be managed, congress passed an appropriations bill in 1908 which allowed the Forest Service ample access to financial means for pursuit of an aggressive fire management policy (Pyne, 1982; Busenberg, 2004). With time, a cooperative network of fire management was formed with the USFS working with both states and other federal agencies (for example, the National Park Service). In 1924, the Clark-McNary Act passed, which allowed the USFS to work cooperatively to suppress fire on any forested land, even land that was not owned federally (Busenberg, 2004, Pyne 1982). Further policy shifts and cooperative fire management efforts including the Federal Wildland Fire Management Policy of 1995/2001 designate how agencies interact to manage wildland fire (USDA/DOI, 2009).

Recognizing the increasing complexity of fires that cross boundaries of land management agencies and partners, in 2002, the Wildland Fire Leadership Council (WFLC) was established by the Secretaries of Agriculture, the Interior, Defense and Homeland Security to oversee the

Federal Wildland Fire Policy (USDA/DOI Forests and Rangelands). Key stakeholders in policy formation and cooperative Fire Management today include subsidiary agencies under each branch of leadership (Agriculture, Interior, Defense and Homeland Security) that comprise the WFLC as well as members of state, Tribal, county and municipal governments, which have limited representation on the WFLC. Some notable stakeholders include the USFS, the Bureau of Indian Affairs (BIA), the National Park Service, and the US Fish and Wildlife Service, Bureau of Land Management (BLM), U.S. Geological Survey, and the Department of Homeland Security Fire Administrator (USDA/DOI Forests and Rangelands). The WFLC established a partnership between the USDA and the DOI called "Forests and Rangelands" to provide communication and information for intergovernmental agencies and partners in fire management and policy efforts. The National Wildfire Coordinating Group (NWCG) also exists to coordinate fire management and fire management strategy across agencies (NWCG).

2. Discussion

2.1 Stakeholder Engagement and Participation

Modern stakeholder engagement and participation in fire policy development and implementation remains complicated. In 2001, the Secretaries of the Interior and Agriculture prompted a review of the 1995 Federal Wildland Fire Management Policy, and an interagency Federal Wildland Fire Policy Review Working Group was responsible for reviewing and updating the policy (USDA FS, 2001). This update focuses on philosophical and policy aspects of federal fire management and fire-management related activities. It addresses the complexity of fire management at the Wildland Urban Interface (WUI) and includes new directives to focus on ecosystem sustainability, science, education and communication (USDA FS, 2001). 2001 also

saw the release of the National Fire Plan, which provides direct guidance on inter-agency cooperation for reducing fire risk and tactical fire management efforts (USDA FS, 2001). Due to confusion over the implementation of Federal Wildland Fire Management Policy (1995/2001), in 2009 "Guidance for Implementation of Federal Wildland Fire Management Policy" was created after prompting by the NWCG and the WFLC. This guidance calls for a more unified effort for fire management between agencies, increased accountability and standardization of methods, as well as increased communication to non-federal stakeholders (USDA/DOI, 2009).

In both the 2001 Federal Wildland Fire Management Policy Update and the 2009 Guidance for implementation, cooperation and involvement with non-agency stakeholders appears to be a top-down, one-way communication system. For example, the 2001 policy update addresses communication as follows "Agencies will enhance knowledge and understanding of wildland fire management policies and practices through internal and external communication and education programs" (USDA FS, 2001). This language is directive rather than cooperative. It is clear that the goal is to help agencies and the public understand the policies and practices in place rather than interact in a participatory manner to address fire management strategies and goals. While local and non-federal stakeholders did have some input as there are limited board positions available on the WFLC which oversees the Fire Management Policy Implementation, it is clear that the policy is not meant to include a diverse set of stakeholders in policy development or implementation. The primary means of input that is intended to update and guide evolution of the Fire Management Policy through time is the inclusion of scientific research. This language is as follows: "Fire management plans and programs will be based on a foundation of sound science. Research will support ongoing efforts to increase our scientific knowledge of biological, physical, and sociological factors. Information needed to support fire management will be

developed through an integrated interagency fire science program" (USDA FS, 2001). It is surprising and notable that rather than include efforts or opportunities for community collaboration to determine sociological concerns, scientific research will instead be conducted to do so. This is echoed by language in the 2009 Guidance directive which discusses "building and developing understanding with the public" for the fire management policies and practices (USDA/DOI, 2009). This also seems to indicate unidirectional communication for the agencies to inform the public, rather than a collaborative effort on policy development.

The USFS does have directives to engage the public in land management planning, but these give great flexibility in how public input and community collaboration are employed, meaning that level of community and stakeholder participation varies based on location and leadership. The National Forest Management Act of 1976 required the Forest Service to develop rules for land management planning and revision. Prior versions of the Planning Rule were developed in conjunction with a committee of scientists, but the 2012 Planning Rule was developed with Tribal input and after a series of national and regional roundtable discussions where they sought public input (USFS, 2011). This rule was designed to eliminate some of the challenges that earlier versions faced including complexity and drawn-out processes for public input. One of the goals of the 2012 Planning Rule is to "Provide for a transparent, collaborative process that allows effective public participation" (USFS, 2011). The main directives regarding public input and collaboration include a period of public input, and flexibility to determine at the local level how the public should be engaged.

The USDA FS also engages the public for fire management at the community level through use of Community Mitigation Assistance Teams (CMAT) to "build sustainable local capacity for community wildfire mitigation during high-risk times before, during and after a wildfire"

(USDA FS, CMAT). Communities with high populations living in the WUI are especially encouraged to develop fire mitigation plans. This type of community involvement is valuable in that it allows communities to develop fire mitigation strategies and community wildfire protection plans (CWPP) that work at the local level, however the decisions made at the community level under these programs do not feed back into fire management plans at the state or federal level, and seem to fall under the directives of the Federal Wildland Fire Management Policy for educating the public.

2.2 Western Scientific Fire Management vs. Indigenous Fire Management

Compared to fire management of the past where foresters and industry professionals were viewed as the experts, modern fire management has placed a strong emphasis on the importance of scientific input in fire management and planning. Using scientific input in fire management planning is one of the major tenets of the Federal Wildland Fire Management Policy (USDA FS, 2001). Community involvement in fire management planning and collaboration with other parties that may have valuable local knowledge such as tribes are primarily described in the Federal Wildland Fire Management Policy as the recipients of policy and management information. Science is the only method clearly described in the policy that is supposed to modify management plans going forward.

Science is a valuable tool for environmental management, but it should not be the only tool utilized. Fine scale scientific inquiry can provide information on the nutrient levels in the soils and identify small scale biotic and abiotic changes pre and post-fire which can tell us how fire, or absence of fire may impact forest health. Larger scale surveys of fuel loads, tree density, and tree species composition can give us insight into how a particular forest might respond to a fire under

selected scenarios and allow managers to determine how resilient and healthy a forest might be. Scientific inquiry for ecosystem management also has drawbacks however: it is frequently disconnected from the management area, with studies being conducted by researchers with no real-world knowledge of the area of interest, and scientific questions being decided by prior existing research rather than consultation with community members who may have extensive local knowledge about ecological problems (Cochran et al., 2008, Marchand et al., 2020).

Scientific studies also tend to be very narrow, focusing on a small piece of an ecosystem over a short time-scale, which then may be scaled up temporally or geographically and applied to larger areas or different ecosystems than the results may actually warrant (Marchand et al., 2020). Understanding wildfire and ecosystem impacts of fire continues to be a challenge for scientists. Fires and fire management in forested ecosystems is highly complex and even the most accurate fire prediction models struggle to match the behavior of fires in real life due to the challenges of accurately measuring and estimating environmental variables (Tardivo et al., 2017). In addition to this, impacts of fire and fire exclusion may have legacies that last for decades or even centuries, far longer than most studies are capable of monitoring (DeLuca et al., 2006; Zackrisson et al., 1996). These struggles become even more prescient when science is used as the only knowledge source for fire management policy.

Fire management for state and federal agencies is also challenging because management decisions have to take into account policy and funding concerns. Decades of fire suppression have resulted in overstocked forests that burn much differently than historical forests. Climate change has resulted in a drier, hotter and longer fire season for many areas. These perturbations result in fires that occupy larger areas and shifted fire regimes that impact how forests burn (Busenberg, 2004; Dale, 2006; Noss et al., 2006). For these reasons, the costs for fire mitigation

and fire management continue to increase on a yearly basis (Bayham & Yoder, 2020). These increased costs often result in judgment calls on what which areas will receive treatment to mitigate future fires, and which areas might be left to burn should a fire occur. The human element of management and coordination in addition to environmental variables make fire-management a complex arrangement. It is surprising given the complexity of modern fire management that alternative management viewpoints and knowledge sources are not considered, particularly where community stakeholders such as tribes are concerned.

In contrast to the top-down management strategies and emphasis on Western science employed by state and federal agencies, Indigenous groups such as Sovereign U.S. tribes, tend to employ a more diverse set of methods for environmental management. Due to the fact that many tribes in the United States were relegated to small tracts of land that was deemed undesirable for farming during colonization, tribes today manage 16 million acres of forested areas in the U.S. on pieces of their ancestral homeland (Davis, 1993). Many of these tribes practiced sustainable land management practices prior to colonization and have adapted to do so on their current land to this day to varying degrees (Marchand et al., 2020). Tribal land management practices tend to be rooted in Indigenous Ways of Knowing (IWK).

IWK have been shown to be a valuable method for dealing with complex scenarios. A study by Berkes and Berkes described Indigenous Knowledge as a form of fuzzy logic (F. Berkes & M.K. Berkes, 2009). Fuzzy logic is a mathematical system for dealing with high levels of complexity and uncertainty, which can be very useful for ecosystem logic (F. Berkes & M.K. Berkes, 2009). IWK is an epistemology that allows Tribal managers to readily address complex disturbance scenarios like wildfire. Tribes are also able to monitor system changes over time and compare that to historical conditions because their land managers and other environmental advisors may

live in the area, rather than conducting studies over small temporal and geographical scales which is common for researchers who are disconnected from the study area (F. Berkes & M.K. Berkes, 2009; Kimmerer, 2002).

Tribal management in the United States takes a holistic perspective, thinking about all the parts of the ecosystem and how they work together (Marchand et al., 2020). This means that the Tribes are not only concerned about fire impacts on trees and endangered species, but also water quality, food availability for game animals, impacts to medicinal and food plants, and impacts to other animals in seemingly disconnected ecosystems. Holistic values, historical land knowledge, and ecosystem monitoring through time allow tribes to manage lands for ecosystem health and biodiversity (Marchand et al., 2020).

Fire is something many U.S. tribes utilized for land management for thousands of years prior to European contact. Fires both human and natural in origin, helped tribes to maintain conditions beneficial to culturally important animal and plant species and to promote ecosystem health (Kimmerer & Lake, 2001). Today, prescribed burning is politically contentious and costly (Ryan et al., 2013). Due to the costs associated with firefighting, tribes have largely been unable to practice traditional burning practices (Knauf, 2015). Tribes have to rely upon state and federal firefighting resources to protect their land and are given little money for additional management or fire mitigation. Tribal land managers today work with federal and state managers, scientists and other non-Tribal entities to make the most informed decisions for their land, while preserving Tribal values and using IWK in their management strategies.

Due to the political and bureaucratic nature of federal land management agencies, even when science changes, land management is slow to adapt because they are beholden to layers of

regulation, time periods for public input and internal politics. For these reasons, management may lag behind ecosystem needs and best practices for years, resulting in continued problems with ecosystem health (Busenberg, 2004, Stephens & Ruth 2005). Some treatments such as post-fire salvage logging must be carried out in a timely manner after a fire, or the timber loses all value. Conflicting opinions on the environmental impacts of pre and post-fire treatments such as salvage logging and prescribed burning have also led to instances of federal agencies being sued to stop them from doing so, even from non-local entities, holding up treatments until it is no longer feasible to carry them out, and creating costly court battles (Peterson, 2015).

While management plans often have both benefits and drawbacks, pre and post-fire treatments must have some room to be carried out and studied to work toward ecologically sound best practices. Tribal land management has more freedom to act quickly and adapt to concerns on their land because there are some federal regulations they are not required to comply with (Ranco & Suagee, 2007). Environmental regulations and reviews are important and should not simply be eschewed, however, the multiple competing requirements of different environmental laws can be challenging to assess and plan for in the natural environment (Stephens & Ruth, 2005).

The current model is not streamlined and results in federal and state agencies moving much more slowly than tribes to test new scientific treatments, conduct studies, and modify management plans. Since tribes are also residing in their management areas, they are able to continuously assess treatment progress and ecosystem health over an extended period of time (Berkes, 2009). In contrast, federal and state agencies may face challenges on a yearly basis due to shifting revenue streams and shifting political priorities that don't arise from the needs of management areas. This can result in scientific studies being conducted on compressed time scales that do not

reflect treatment impacts on an ecosystem through time. This research conducted on short temporal scales may be used to select management decisions that are not informed as to longer term impacts on the management area. These challenges show a clear need for federal and state agencies to consult with and work more intimately with land managers using alternative perspectives and methods.

3. Conclusions

3.1 Holistic Fire Management and Community Participation: Moving Forward Together

While community involvement and collaboration are required for USFS management plans, community stakeholders such as Tribal managers are not seen as information sources for ecosystem knowledge or fire management strategies. Rather, stakeholders and managers at the state and federal level are expected to collaborate in order to understand and carry out pre-determined management plans designed at the federal level and informed by current science. Lack of input and agency given to local stakeholders may lead to distrust and resentment of federal policies, priorities and oversight. Communities are the ones that deal with the consequences and impact of fires long after the firefighting is over, and it is important that they are able to have a voice in fire management decisions. Fire management for the human element is a delicate balance.

Different community stakeholders often have competing goals that may conflict with one another or even ecosystem needs. For example, despite known environmental benefits of prescribed burning, carrying out prescribed burns or any sort of fire-mitigation strategy can be challenging (Dale, 2006). Implementation of prescribed burning for example, has to contend with several

federal policies including the Clean Air Act, Clean Water Act, National Environmental Protection Act, and the Endangered Species Act (Dale, 2006, Ryan et al., 2013). Managers have to analyze their plan to comply with each regulation, which can be costly and time consuming. There is also legal liability that requires prescribed burns to employ ample resources to prevent out of control fires and excessive smoke (Ryan et al., 2013).

Communities living near areas that need to undergo prescribed burning for ecosystem health, being unaccustomed to seasonal wildfire smoke due to decades of fire exclusion but informed about the negative impacts of pollution can often be opposed to prescribed burns (Ryan et al., 2013). Management techniques such as prescribed burns may also balance short term consequences with long term ecosystem needs, meaning the effects and benefits may not be observed in a short enough timetable for some scientific studies or the public to appreciate. Combined with decades of fire suppression propaganda and the negative publicity associated with prescribed burns that go awry, prescribed burning can be a hard sell to many community members (Ryan et al., 2013).

Priorities laid out in federal fire management plans also frequently conflict with the interests of stakeholders. For example, the Federal Wildland Fire Management Policy of 1995/2001 places human life and public safety as the first priority with resources and property based on value as the second priority in fire suppression, however human and community structures are generally protected above timber and other ecosystem resources regardless of value difference (Bayham & Yoder, 2020, USDA FS, 2001). These value judgements have the capacity to create conflict when some stakeholders are given preference over others. For example, in 2015, the Cougar Creek Fire burned 41,500 acres of Yakama Tribal forest, over 20% of their commercial timber land (Knauf, 2015). Tribal leaders and land managers were frustrated because during that fire

season, multiple fires resulted in firefighting resource limitation and resources were diverted from the reservation to areas around Lake Chelan where wealthy people had built expensive vacation homes that were at risk of fire (Knauf, 2015). The tribe had specifically chosen not to build homes in forested areas, and because of this decision they ended up losing more value than community members nearby who chose to put homes in areas at risk of fire danger.

Tribal land frequently takes a backseat in fire protection regimes, given that it is not densely populated. These losses have lasting impacts both economically as well as culturally. Tribes tend to manage lands on a long time-scale to provide for future generations, and ecosystem disruptions can have lasting impacts. The land is also a fixed resource for the tribes, and they rely on it to sustain them. Someone with a vacation home on Lake Chelan could very well afford to purchase a new vacation home either in the same spot or elsewhere, and even be reimbursed by insurance. In comparison, impacts to fish or game animals, which cannot be insured, are not able to be replaced. This makes valuations of property to be protected during wildfire events an area of concern and difficulty.

Balancing priorities and making judgements about who should receive assistance during fire events and how to manage land to mitigate fire risk is something that should be thought out in advance and should involve local stakeholders impacted by the decisions. Deciding how to incorporate stakeholder knowledge and balance competing objectives is no easy task. Studies have shown that incorporating stakeholder knowledge into resource management plans can have benefits such as more robust and holistic plans, but it can also have drawbacks such as increased complexity and challenges identifying outcomes of management plans (Gray et al., 2012).

Research has also shown that informal decision-making processes with multiple stakeholders may increase power differentials, and that legislation for community participation in environmental decision making needs to be strong and enforceable to protect those with the least power (Cole, 1999). Yet top down decision making as it stands has had devastating social, economic and ecological consequences, including putting stakeholders and management agencies at odds, and long-lasting negative impacts on ecological sustainability (Holling & Meffe, 1996). Corburn (2003) asserts that local communities who face the risk of planning decisions should never be ignored because they have valuable local knowledge to contribute, both technical and political that may be ignored by outside decision makers. For these reasons, wildfire management must become a reciprocal knowledge building process.

It is challenging to identify which stakeholders are most deserving of representation in land management planning. My recommendation, though it may be controversial, is to focus on those with the highest knowledge and intimacy with the land as well as those peoples and communities who are most impacted by and vulnerable to land management decisions. For example, forest managers, tribes and community members who have worked with or resided on the land for extended periods of time are more likely to have expertise and understanding that would add value to land management plans. People who have vacation homes in the area but reside elsewhere, and commercial logging companies generally have their assets insured and can re-locate or rebuild in the event of a disaster, and while land management plans certainly impact them, they have less to lose than for example, a Tribal member or community member that cannot afford to move should the local environment be devastated. So, while all stakeholders should be considered, some may be more important than others to develop sustainable and equitable long-term plans and balance the power differentials described by Cole (1999).

Tribal managers in particular should be considered as one of the more important stakeholders, given the extensive historical and modern day place-based knowledge tribes possess about the land, the value of utilizing IWK in addition to Western scientific knowledge for developing a complete picture of ecological systems, and the cultural, economic and spiritual value of the land for tribes in comparison to other stakeholders. I have summarized these guidelines in a graphic that could be used by federal and state agencies to prioritize stakeholder engagement (Appendix A, Figure 3.1). While this graphic is incomplete in that it does not account for some of the concerns that might be present in a given management area due to potential differences in environment, land ownership, community, and socio-political landscape, I believe that it is a good starting point. It could be used to assign weights to stakeholder preferences in management plan modeling by using techniques such as the Analytic Hierarchy Process as described by Ananda and Herath (2003).

Placing the interests and values of tribes over other stakeholders in some instances is likely to present challenges as it is a threat to the status quo, and people and entities with wealth and power are generally used to being treated as a priority. In order to overcome help ameliorate these challenges, I believe that institutionalizing traditional knowledge as a legitimate knowledge source in the way that science is viewed is necessary. Institutionalization as described by Meyer and Rowan (1977) is the process through which things gain a rule-like status in social thought and action. In the modern era, science is very much institutionalized in Western thought, policy and practice, which is why its inclusion in K-12 education and fire management policy is taken for granted, rather than contested. According to Meyer and Rowan,

> "*Organizations are driven to incorporate the practices and procedures defined by prevailing rationalized concepts of organizational work and institutionalized in society. Organizations that do so increase their legitimacy and their survival prospects, independent of the immediate efficacy of the acquired practices and procedures*" (1977).

Using institutional theory, IWK and Tribal fire management practices can gain legitimacy and institutionalization by developing a formal structure that adheres to the notions of existing organizations. Like Western scientific knowledge, IWK can gain legitimacy through a steady campaign of informing and educating the lay public at both the K-12 and college level, through establishment of formalized programming, and through infiltration to popular culture such as media, art and literature.

Methods and guidelines to incorporate traditional Indigenous ecological knowledge (TK) into systems using scientific based ecological knowledge (SEK) have been developed by Tribal elders and members of the scientific community, and strongly echo some of the tenets that will allow it to gain legitimacy as an institution (Mason et al., 2012). Recommendations out of a two-day conference in 2010 included:

> 1) the development of a national program to educate on IWK/SEK and knowledge integration that would be tailored to regional needs based on tribes, community and agencies;
>
> 2) workshops conducted by keepers of IWK to inform and educate land managers and scientists, collaborative and local development of relationship protocols between tribes

and land-management agencies, encouragement of career residency for resource professionals in federal agencies to establish long lasting relationships with tribes;

3) increased partnership between Tribal and non-Tribal colleges and investment in cross-cultural research and Tribal representation and retention in academia, research and scholarship, joint SEK/IWK environmental research collaborations;, and

4) expansion of the scientific research outlets to include education and workshops accessible to Tribal communities, and cross-jurisdictional experiential learning efforts (Mason et al., 2012).

Pat Pierre, Salish-Pend d'Orielle elder in attendance, stated that the overarching goals should be "a simple prescription for crosscultural progress: open communication, education, respect, and friendliness" (Mason et al. 2012).

The development of a national platform could allow IWK to gain legitimacy in the mainstream public, particularly if it is incorporated into K-12 education and taught alongside SEK. In addition to these efforts, clear, enforceable legislation needs to be passed that promotes Tribal managers to key stakeholders for land management planning and fire management planning at the state and federal level, and the Federal Wildland Fire Management Policy (1995/2001) should be amended to reflect this, with IWK being added as a source for policy and management evolution.

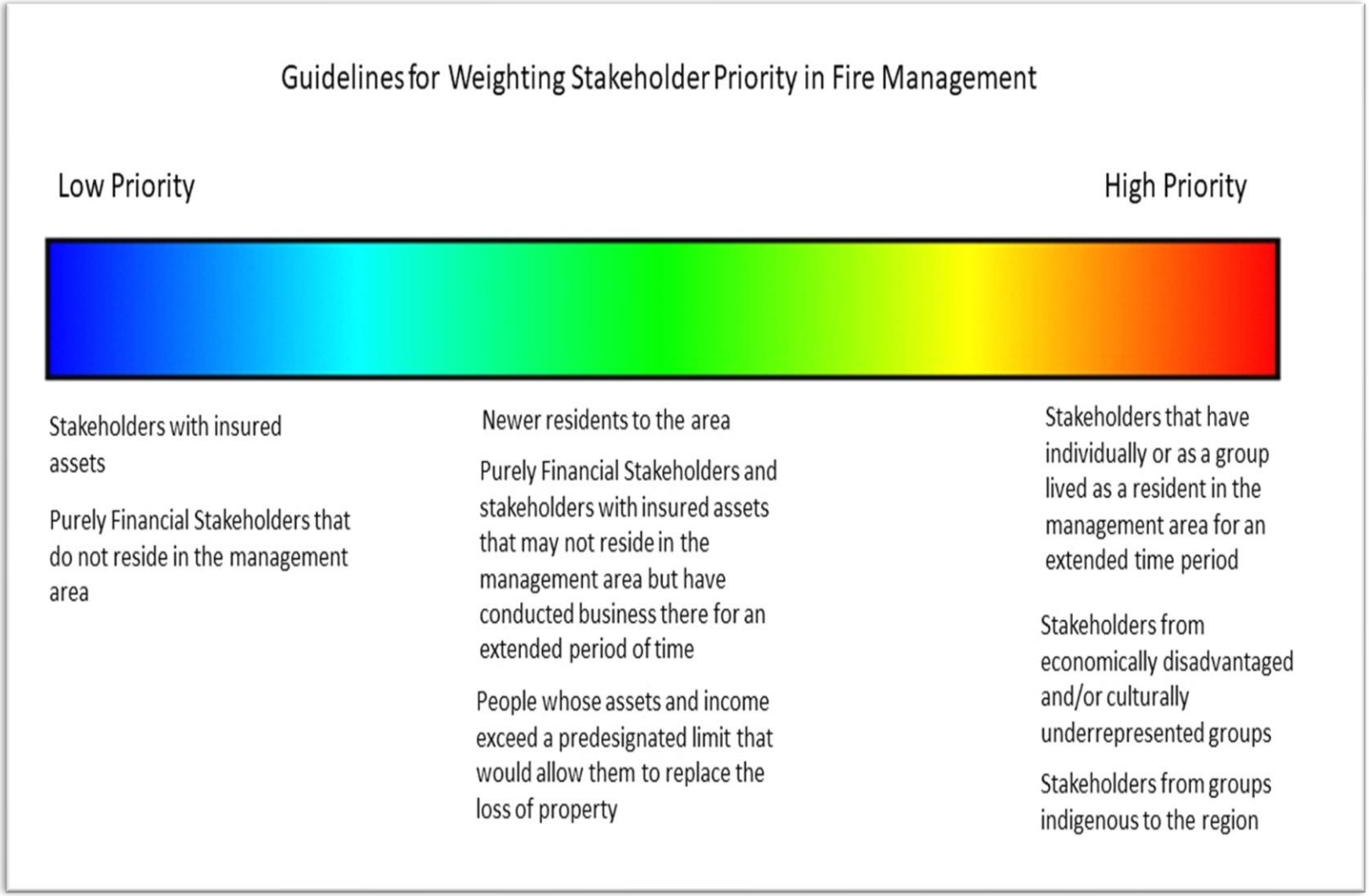

Figure 3.1 Guidelines for Prioritizing Stakeholder Engagement for Use by Federal and State Agencies

Appendix B: Glossary of Terms

BIA: Bureau of Indian Affairs

BLM: Bureau of Land Management

CMAT: Community Mitigation Assistance Teams

CWPP: Community wildfire protection plans

Indigenous Ways of Knowing/Traditional Ecological Knowledge (IWK): An understanding of the relationship between humans and the environment gained over a period of time and carried out and understood through spiritual and cultural practices and beliefs. A holistic knowledge building process

NWCG: National Wildfire Coordinating Group

Scientific Ecological Knowledge (SEK): Knowledge derived from the scientific methods utilized in Western traditions

USDA: United States Department of Agriculture

USFS/USDA FS: United States Department of Agriculture Forest Service

USDHS/DHS: United States Department of Homeland Security

USDOI/DOI: United States Department of the Interior

Western/Westernized: Deriving from the cultural history of Europe and North America

WFLC: Wildland Fire Leadership Council

Wildland Urban Interface (WUI): transition zone between unoccupied (often forested) land and areas of human development

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Chapter 4. Indigenous Environmental Advocacy: Mitigating Climate Change

Abstract

Industrial nations presently greatly influence climate change policy, but Indigenous groups should not be ignored in their ability to address climate change. The impacts of anthropogenic climate change are expected to have devastating impacts to many of earth's environments, which will harm populations in many countries. Indigenous people who often rely more closely on the environment for culture and survival, are expected to be some of the groups that will face the most dire consequences of these environmental changes. In the United States, Indigenous Tribes have shown leadership on environmental legislation, and have led a number of successful environmental movements. This is particularly notable given that addressing climate change is as much of an ideological challenge as it is a practical one. A history of using Indigenous Knowledge forming processes to adapt to new environments and Indigenous advocacy around the world for climate change mitigation and preparedness has shown that Indigenous people should be considered key leaders by Industrial nations.

1. Introduction

Indigenous peoples, that is, communities of people living on their ancestral homelands and/or following cultural traditions that can be traced back to the original inhabitants of an area, have been fighting to retain environmental, cultural and political rights since the beginning of colonization (Brown, 1994; Clark, 2002; Deloria et al., 2016; Doolittle, 2010; Nadasdy, 2005). These challenges continue into the modern day, as industrialization, neo-colonialism, and post-industrialized countries chip away at protections for the land, both historically Indigenous but occupied by the descendants of colonizers and modern-day immigrants, as well as land currently utilized by Indigenous communities. Indigenous activists through their battles both in and out of court, have made considerable impacts on both environmental policy as well as modern day environmental movements (Brown, 1994; Clark, 2002; Deloria et al., 2016, Doolittle, 2010).

Indigenous groups are often looked to as leaders in environmentalism as a result of ongoing environmental activism in addition to the spiritual and cultural beliefs that many Indigenous peoples employ in relation to the land and environmental stewardship (Moore, 1998; Willow, 2009). Scholars like Nadasdy (2005) however, have argued that the Western concepts of environmentalism and conservation do not accurately describe the cultural and spiritual practices that Indigenous peoples utilize when interacting with the environment. In contrast to the Western view of Indigenous groups being “ecological nobility”, studies have shown that Indigenous communities have not always lived in a manner that is environmentally sustainable, nor do all Indigenous communities today (Diamond, 2004). Despite this, there is ample evidence to suggest that some Indigenous groups have an in-depth understanding of complex ecological relationships and processes developed through time and intimacy with the local environment that allows them to manage land sustainably both historically and in modern times (F. Berkes & M.K. Berkes,

2009). It can also be argued that in areas where Indigenous people have been allocated small finite land areas to reside upon and manage such as the reservations in the United States, there has been additional pressure for Indigenous groups to manage lands sustainably to provide for their communities spiritually, culturally and economically (Marchand et al., 2020).

The application of labels such as environmentalism and sustainability to describe Indigenous relationships with the land is oversimplified and ethnocentric (Nadasdy, 2005). Rather than simply participating in environmental activism due to Western environmental ideals, Indigenous activism is strongly rooted in a struggle for sovereignty, control of Indigenous land and resources and the protection of cultural and spiritual practices which are often innately tied to the environment resources (Brown, 1994; Clark, 2002; Deloria et al. 2016; Moore, 1998; Willow, 2009). Despite these nuances, Indigenous groups have often had to accept and adopt these labels and roles as they fight to protect their sovereignty, rights and way of life in Westernized societies (Nadasdy 2005). In many cases, Indigenous groups have been successful at forging alliances with non-Indigenous environmental activists to enact political change over shared interests (Moore, 1998; Lipsitz, 2008).

Indigenous groups today are well known for their leadership in environmental movements. As countries have continued to industrialize and Westernize, Indigenous groups throughout the world have had to fight to retain their sovereignty, cultural and spiritual practices, and access to environmental resources (Brown, 1994; Clark, 2002; Deloria et al. 2016; Moore, 1998; Willow, 2009). These fights have taken place in courts, via protests, in education systems, in academia, in the court of public opinion, and even physically on the land itself. The success of these battles is variable, socio-political, economic and other factors in different countries and locale can often dictate how the government and the non-Indigenous communities respond to Indigenous

assertions of their sovereignty and rights. In developing regions such as and Latin America and parts of Africa, Indigenous environmental activists today often face hostile and life-threatening conditions. In Latin America in particular, environmental human rights defenders (EHRDs) face criminalization and murder as they fight to prevent industrial exploitation of their ancestral territories (Birss, 2017).

Despite the fact that many Latin American countries have laws calling for the consultation with Indigenous people regarding land use and protections for Indigenous peoples, many Latin American governments today disregard these rights in favor of the interests of industry and even foreign corporate influence. In addition to this, many Latin American countries have passed laws to bend environmental rules and to criminalize protest and imprison EHRDs arbitrarily. Government and corporate interests (often from the U.S. and European nations) also engage in campaigns to terrorize, defame and discredit EHRDs and their movements. Most troubling is the refusal of most governments to look into or prosecute murders of EHRDs, resulting in 577 EHRDs being killed between 2010 and 2015, the highest murder rate of EHRDs globally (Birss, 2017). The political instability and corruption in the region that allows governments to prioritize business over civil rights is not surprising given that many of these governments have been ravaged over the years by foreign intervention and dictatorships creating economic instability.

The U.S. in particular contributed greatly to instability in the region, providing direct and indirect support for overthrowing democratically elected left-leaning leaders in favor of right-wing authoritarians, military leaders and dictators during the cold-war era, and continuing with neo-colonial efforts in the early 20th century to promote the occupation and control of the region by U.S. business interests (Galeano 1977, Chasteen 2001). This legacy and the power of U.S. and European business interests in the area continues to this day, threatening the land and

livelihood of Indigenous people throughout the region. Indigenous groups in wealthier industrialized countries with stable governments face similar struggles against business and government interests and ongoing oppression, but have access to different avenues to pursue justice.

In the United States, Indigenous activism became truly prescient during the 1960's, a window of opportunity during which other civil rights movements were also taking place and the country was in a time of intense social change (Rios, 2002). Indigenous tribes in the United States up until that point had suffered hundreds of years of oppression, genocide, land theft, forced assimilation, relocation and efforts at termination of Tribal rights (Churchill, 1997; Rios, 2002). While tribes had established treaties with the United States in regard to sovereignty, land use, control of resources and the right to continue spiritual, cultural and environmental practices, the U.S. government had for decades violated or ignored the treaties. The Bureau of Indian Affairs (BIA) which had been established to manage lands held in trust for tribes, allowed companies and other agencies access to below market values for land and resource use on Tribal lands, keeping tribes that should have been wealthy impoverished.

The American Indian Movement (AIM) was founded in 1968 by a group of Anishinabe community members (Churchill, 1997; Rios, 2002). The movement, focused on local civil rights in the Minneapolis area initially, and grew to comprise members of tribes throughout the U.S., with the goal of asserting Tribal sovereignty and regaining control over lands, territories, and resources therein. This movement, later called the Red Power movement, gained traction, and soon organizers were holding demonstrations to call attention to issues facing Native Americans (Rios, 2002). The U.S. government, not being fond of the methods utilized and with the desire to retain the status quo eventually criminalized the movement, labeling AIM as a terrorist

organization, and imprisoning a well-known leader of the movement, Leonard Peltier on claims that he had murdered two FBI agents. Despite these attempts to end Native American activism, in the decades that followed, it began to grow stronger (Churchill 1997, Rios 2002).

In the 1980s and 1990s, when the environmental justice movement gained traction in the U.S., tribes were already poised to be leaders and contributors to continued environmental fights (Clark, 2002). This is not surprising given the long history of Tribal land and sovereignty being trespassed upon in order for corporations and government entities to extract natural resources and utilize valuable land. The trust status of Native American Lands was utilized starting in the 1920's to justify mineral extraction, with the BIA and federal government going so far as to reorganize tribes in 1934, establishing Tribal councils friendly to corporate interests (Churchill, 1997).

Corporations took advantage of the sovereign status of Tribal land, ignoring federal environmental regulations. Despite the intense resource extraction of minerals, oil, natural gas, coal and uranium, tribes frequently saw little to no profit, and job creation was promised but never occurred. Tribes did however, bear all the burden to ameliorate any environmental issue created by these operations (Churchill, 1997; Clark, 2002). Fighting for treaty rights such as fishing also strongly entrenched tribes in the fight for environmental protection. For example, the right to fish for Salmon was established in the Treaty of Point Elliot by Western Washington Tribes but was ignored by the government, with dams and environmental regulation killing the Salmon, and Native Americans harassed and criminalized for attempts to fish (Deloria et al., 2016; Brown, 1994). Only after Vine Deloria Jr. appeared on national television with photographs of brutality against native Americans did the federal government intervene to sue Washington State to honor the treaty rights (Deloria et al., 2016). This decision became known

as the Boldt decision, which indicated that tribes not only had the right to fish, but that the fish had to be protected from environmental degradation.

While other cases dealing with fishing rights came prior to the Boldt decision, this case set a precedent for tribes to argue for environmental protections in conjunction with their treaty rights (Brown, 1994). After this decision, tribes throughout the nation have continued to fight in and out of court to protect treaty rights and assert sovereignty and the ability to manage and control their lands and resources. In the 1980's, tribes began to be included in co-management for fisheries and water resource management (Brown, 1994).

Tribal involvement in environmental policy has allowed them to achieve legitimacy as vital stakeholders in both local and federal initiatives for land management. In addition to co-managing fisheries and water resources, Tribes in the U.S. are also managers and co-managers of many forested areas, where they manage land to provide spiritual, cultural and economic benefit in a sustainable manner (Berkes, 2009). In contrast with the Westernized Scientific Ecological Knowledge (SEK) utilized by federal and state land managers, Tribal nations tend to utilize Indigenous Ways of Knowing (IWK) based on a long history of intimacy and cultural engagement with the land as a management framework (Berkes, 2008; Marchand et al., 2020).

Tribal managers also utilize SEK and collaboration with outside agencies and partners to achieve management goals (Berkes, 2009; Marchand et al, 2020; Moore, 1998), but IWK allows them a more holistic understanding of complex natural systems which allows them to manage sustainably. Land management in the U.S. as elsewhere, suffers from short-sighted economic and scientific measurements of progress, is subject to funding cycles, policy changes and the legal and social landscape that puts individual benefit and technological progress above other values.

Tribes certainly have their own internal politics, economic and social concerns to deal with, but the IWK framework and knowledge building process provides balance. Land is managed with multiple interconnected systems taken into consideration. Management priorities are guided by principals of respect for the environment and with an eye on the future, rather than short term gain (Marchand et al., 2020). For example, in a 2015 article by the Seattle Globalist, Yakama Tribal land managers described how they manage land "to look forward seven generations and take care of those people" (Knauf, 2015).

Sustainable land management and traditional knowledge systems have made U.S. tribes the subject of much modern academic and scientific research, furthering their position in the U.S. ideological landscape as environmental leaders. Environmental stewardship and activism by U.S. tribes continues today and has had lasting impacts on public perception of environmental concerns as well as environmental policy both domestically and on the international stage.

Modern movements such as the protests against the Dakota Access Pipeline (DAPL) in the U.S. where the Standing Rock Sioux opposed the construction of an oil pipeline that would threaten the environmental conditions and water on their reservation and violate their treaty rights have gained momentum and mainstream visibility. The DAPL camp brought representatives from over 300 federally recognized tribes and had up to 5000 inhabitants on site, comprised of both Indigenous water protectors and their allies (Johnson, 2017). The #noDAPL movement represented a new era for Indigenous activism in the U.S., as social media allowed water protectors to craft their own narrative and garner support instead of relying on traditional media sources to craft a narrative for them (Johnson, 2017)

Similar movements for Indigenous civil and environmental rights have been carried out by First Nations communities in Canada. For example, the Grassy Narrows First Nation blockade of logging in their traditional territory, and on a larger scale, movements such as the Idle No More Movement which opposed land and water exploitation in bill C-45 and brought light to the Canadian government's mistreatment of Indigenous people and violation of their rights and traditional values (Wotherspoon & Hansen, 2013). Similar to the #noDADL movement, the Idle No More Movement was captivated both traditional and social media platforms. These movements have awakened renewed public interest in environmental activism and environmental policy.

Rather than fitting Western conceptions of environmentalism, these movements often involve environmental concerns because Indigenous people often rely on the land to preserve cultural and spiritual practices, as well as to provide and sustain them materially and economically (Moore, 1998). Many environmental fights are also fought on the basis of human and civil rights for Indigenous groups, for example, protecting Tribal rights and sovereignty (Willow, 2009). While motivations for engaging in environmental activism may differ, both between Indigenous groups and between Indigenous and non-Indigenous activists, the fact remains that Indigenous environmental activism has laid the groundwork for Indigenous participation and leadership in environmental concerns. Indigenous activism, specifically because it addresses human rights in addition to environmental concerns as opposed to Western environmental activism, has also exposed the public to the human implications of environmental disasters such as anthropogenic climate change. For these reasons, Indigenous environmental activism has shaped modern dialogues surrounding climate change.

In addition to climate-change adjacent environmental activism, many Indigenous groups, scientists, scholars and elders have worked more specifically on climate change initiatives, addressing both global challenges, as well as developing individualized plans for their own communities to deal with the impacts of climate change (Berkes, 2009; Whyte, 2017). In the academic field, papers have been published by Indigenous scholars, and presentations at conferences have addressed Indigenous perspectives on climate change.

Numerous tribes such as the Salish-Kootenai Tribe have also developed strategic plans to address climate change. Sheila Watt-Cloutier, an Inuk leader, filed a petition called "The Right to Be Cold" with the Inter-American Commission on Human Rights (IACHR) attempting to hold the U.S. accountable for addressing human rights violations imposed upon Inuit people due to lack of action on greenhouse gas emission mitigation and the resultant impacts of anthropogenic climate change (Whyte, 2017). Despite these efforts, climate change policy is still strongly controlled by the interests of industrialized countries.

2. Discussion

2.1 Climate Change in the Modern Era: Industrialized Nations and Climate Change Policy

Anthropogenic climate change has been viewed as a major environmental and social problem internationally since the 1980's, which ushered in international discussion and work on climate change science and policy (McCright & Dunlop, 2003). The International Panel on Climate Change (IPCC) was formed in 1988 by the World Meteorological Association (WMO) and the United Nations Environment Programme (UN Environment) to assess the state of knowledge on climate change and help countries to make informed policy decisions (IPCC).

The IPCC synthesis report from 2014 states that climate change is extremely likely to be due to anthropogenic greenhouse gas emissions of carbon dioxide, nitrous oxide and methane. The report warns of "severe, pervasive and irreversible impacts for people and ecosystems" (IPCC, 2014). Environmental and ecological consequences include severe unpredictable weather patterns, ocean acidification, sea level rise, loss of ice in colder climates, droughts, flooding, and extinction of plant and animal species. Risks for humans include issues with food security such as famine due to species loss and severe weather patterns, and water scarcity among other things. The report also outlines how people and countries that are already economically disadvantaged stand to suffer the most, despite wealthier countries contributing the most to greenhouse gas emissions. The report warns that mitigation and adaptation strategies are vital to ward off the more severe predictions, however, climate change will already have irreversible impacts even with strict reductions in greenhouse gases at this point.

Many countries have worked to develop adaptation and mitigation plans. In 1997, 160 countries convened to establish the Kyoto Protocol, which was designed to reduce carbon dioxide emissions. 84 countries were signatories and 37 countries made binding commitments to reduce emissions (McCright & Dunlop 2003, UNFCCC). In 2016, the Paris Agreement was established to double down on global efforts to reduce greenhouse gas emissions and reduce global warming. 189 Countries ratified the Paris Agreement (UNFCCC). Under the Paris Agreement, countries are expected to develop tailored plans for Nationally Determined Contributions (NDCs) to greenhouse gas reduction. Many wealthy countries have committed to reducing greenhouse gas emissions in an attempt to soften the blow of climate change, but most have fallen short (Wernick, 2019).

Particularly disheartening is the lack of participation from the U.S. who gave notice of intent to withdraw from the Paris Agreement under President Donald Trump (Wernick, 2019) This is however not particularly surprising, given that conservative anti-environmental forces have been at work in the United States since the 1990's, working to roll back environmental protections, regulations, and refute climate science in order to uphold the status quo where corporate interests take priority in political decisions (McCright & Dunlop, 2003). Given the disparate impacts predicted by the IPCC on marginalized and economically disadvantaged groups and the slow progress on mitigation observed by leadership in industrialized countries, the international community should be working to empower those most impacted by climate change as vital stakeholders in decision making processes. Indigenous groups throughout the world, being reliant upon the local environment, vulnerable to the impacts of climate change, and having traditional place-based knowledge with regards to the environment, should certainly be given the ability to participate on equal footing with the leadership of industrialized wealthy nations to make decisions and provide suggestions for climate change mitigation and adaptation.

Indigenous groups have worked to gain legitimacy within the UN regarding climate change, and the UN has recognized, at least symbolically, the importance of including Indigenous groups on matters of the environment and climate change. In 2000, the International Indigenous Peoples Forum on Climate Change (IIPFCC) was formed to allow Indigenous people a forum to participate in the United Nations Framework Convention on Climate Change (UNFCCC) (Doolittle, 2010). The UN also passed the UN Declaration on the Rights of Indigenous Peoples (UNDRIP) in 2007 which established a framework for the "survival, dignity and well-being" of Indigenous people (United Nations).

Despite these attempts by the UN to legitimatize Indigenous engagement in UN processes such as the UNFCCC, Indigenous people have often been excluded or ignored on climate change initiatives. Take for example, the passage of UN's REDD program (Reducing Emissions from Deforestation and Degradation), which was opposed by a large majority of Indigenous groups due to the potential to threaten Indigenous sovereignty and control over local resources. Indigenous leaders continue to fight for participation in international planning for climate change. Despite the vast diversity of cultural and environmental traditions, Indigenous groups in the IIPFCC have come together to ask for participation in international climate change strategies both because of their valuable ecological knowledge as well as their shared history of exploitation (Doolittle, 2010). It is imperative that the UN work to formalize the importance of engaging Indigenous groups impacted by climate change in a manner that goes beyond symbolic participation.

3. Conclusions

3.1 Going Forward: The Importance of Indigenous Leadership in a Changing Climate

Some people may argue that historical place-based knowledge is no longer relevant in the modern world. After all, climate change is shifting disturbance regimes, weather patterns and the distribution of plant and animal species. Plants and animals that Indigenous groups are familiar with may in many cases cease to exist. However, traditional knowledge (IWK) should be understood as a process of building knowledge, rather than a stagnant pool of knowledge (Berkes, 2009). Traditional Indigenous knowledge building processes as a compliment to scientific ecological knowledge (SEK) is adaptable to modern day land management that can help humans mitigate and adapt to climate change.

Indigenous people have had to adapt their ecological management strategies continuously since colonization began. Forced relocation to different environments and relegation to small tracts of land has shifted the way that Indigenous people live in many areas (Deloria et al., 2016). Many pieces of traditional knowledge have been lost, but the cultural and spiritual values guiding the knowledge building process have not been lost. As a methodology, traditional knowledge allows for the understanding of complex ecological systems that are challenging to address with SEK alone (Berkes, F., & Berkes, M. K., 2009; Kimmerer, 2002).

The values of economic growth and technological progress championed by Western colonizers is what has led to global environmental degradation and anthropogenic climate change. The environmental degradation introduced to Indigenous lands by settler-colonialism has already prepared many Indigenous societies for further challenges as anthropogenic climate change is added to the list of continued impacts of global colonization (Whyte, 2016). For example, Kyle Powys Whyte, a Potawatomi scholar-activist points out that many Indigenous people are already disconnected from the plants and animals that were historically important. (Whyte 2016). As Whyte pointed out, climate change is seen by many Indigenous groups as another continuation of environmental problems brought on by colonization.

Indigenous groups occupy a position in society and the environment that makes them uniquely qualified to assess and address concerns with the changing climate in a holistic, socially-just manner. Indigenous groups have in many instances shown themselves to be experts at adapting to even catastrophic levels of change. Despite horrific historical and modern injustices, Indigenous communities continue to persevere, fighting for human and environmental rights and the traditional values of their cultures. In places like the United States, tribes had to adapt to

being relocated to lands that in many cases were either a small portion of their historical territory, or completely unfamiliar (Marchand et al., 2020).

Overcoming economic and socio-political oppression, many tribes have fought valiantly to preserve treaty rights, and regain control over their resources. Traditional knowledge has allowed tribes to manage their land sustainably in line with their cultural values. Tribes have also become experts (out of necessity) at bridging the gap between Western and Indigenous cultures to achieve their goals and strengthen their ability to persevere in the modern era (Moore, 1998; Lipsitz, 2008). This includes actions such as incorporating SEK into land management while retaining IWK use which has allowed them to gain institutional power and legitimacy as stakeholders in land management decisions at state and federal levels, finding common ground between traditional values and Western views on the environment to forge alliances and garner the support of non-Tribal environmental groups and the public, using the court system to assert their rights and shape environmental policy, and working to bring public awareness to human and environmental rights concerns through activism. This holistic perspective in addition to strategic and targeted action is much needed for mitigation of and adaptation to climate change.

In addition to the environmental leadership Indigenous groups have shown, their involvement in development of climate change policy should be paramount, given that Indigenous groups are likely to suffer the negative impacts of climate change disproportionately compared to non-Indigenous groups (IPCC, 2014). Reasons for this include the economic marginalization of many Indigenous groups, the reliance on the land for cultural, spiritual and economic sustenance, and the unintended human side effects predicted by IPCC reports such as wars caused by human migration and food and water scarcity (IPCC, 2014). Further, many Indigenous groups occupy areas targeted by scientists as important for conservation, while simultaneously rich in resources

and thus targeted by commercial interests for exploitation. Climate change will certainly continue to shape policy and economic sectors surrounding Indigenous land and land use, impacting the lives of Indigenous people throughout the globe.

A legacy of strategic environmental activism, sustainable land management and holistic thinking about social and environmental concerns has allowed many Indigenous groups around the world to adapt to changing socio-political and environmental conditions. Indigenous communities have shown leadership and the ability to fight for traditional cultural values while simultaneously finding common ground with non-Indigenous groups to fight for shared values such as environmental preservation. Indigenous communities will also disproportionately suffer the negative impacts of climate change. For these reasons, Indigenous groups must be provided greater institutional power both within their nation-states as well as at the international level to help assess and address anthropogenic climate change. Globally, leaders need to make room for Indigenous communities to participate in important conversations, while taking care not to box them into roles where they must play out Western conceptualizations of "ecological nobility". A collaborative and respectful approach is likely to help build a more sustainable future for the environment.

Appendix A: Glossary of Terms

AIM: American Indian Movement

BIA: Bureau of Indian Affairs

DAPL: Dakota access pipeline

EHRD: environmental human rights defenders

IIPFCC: International Indigenous Peoples Forum on Climate Change

Indigenous: communities of people living on their ancestral homelands and/or following cultural traditions that can be traced back to the original inhabitants of an area

Indigenous Ways of Knowing/Traditional Ecological Knowledge (IWK): An understanding of the relationship between humans and the environment gained over a period of time and carried out and understood through spiritual and cultural practices and beliefs. A holistic knowledge building process

IACHR: Inter-American Commission on Human Rights

IPCC: International Panel on Climate Change

NDC: Nationally Determined Contributions

Scientific Ecological Knowledge (SEK): Knowledge derived from the scientific methods utilized in Western traditions

UNDRIP: UN Declaration on the Rights of Indigenous Peoples

UNFCCC: United Nations Framework Convention on Climate Change

Western/Westernized: Deriving from the cultural history of Europe and North America

WMO: World Meteorological Association

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Chapter 5: Research Synthesis

Environmental problems are as complex and dynamic as the natural landscapes they occur on. They cross geo-political boundaries, resulting in the need for increased collaborative efforts to tackle them. Diverse perspectives, and the engagement of local stakeholders hold the key to developing robust and lasting political and management strategies to pervasive environmental concerns. Anthropogenic climate change, once a scientific specter, has materialized, and is a reality in today's world. Those who have the least socio-economic power, are those that will be the most impacted by the future realities of climate change. Those of us with some modicum of privilege in this world that allow us to raise our voices bear the responsibility of helping to amplify the voices of those who hold little privilege. We must take this responsibility on carefully and respectfully, with our hearts and our ears open.

A multifaceted approach is necessary to create a society where we are more unified than we are divided. This dissertation has addressed some aspects of environmental education and management through a lens of multiculturalism, diversity, and social justice. The first chapter addressed some of the inadequacies of our current educational system, with an eye on the United States, and Indigenous knowledge on the environment. Lasting systemic change takes time and must start with targeted education initiatives. While the land managers of yore are long gone, today's land managers are a plethora of people with both older, and newer approaches. Despite the reflexivity and openness of many scientists and land managers, they carry with them the institutional memories of an unsustainable and unjust system that has historically excluded diverse epistemologies and pedagogies like Indigenous Ways of Knowing (IWK).

True change that will build resilient ecosystems must begin in primary education and continue through educational initiatives in the community and at occupational levels. The approaches discussed in the first chapter foreshadow the classroom-based interventions that were implemented and tested over three years in a college-level educational setting. While these approaches were developed and designed around U.S. educational settings, they should be tested, modified, and employed by other countries, using culturally competent, place-based methodology.

While Washington State has a curricula requirement for educating students about Tribes, many other states do not have any such requirement. Despite these efforts, lasting partnerships with local Tribes in the classroom remain rare. Tribal education is often focused on cultural aspects and is minimal or absent in STEM classrooms. Environmental science should not be taught disconnected from socio-cultural realities. Humans are cultural beings, rather than the rational and disconnected observers the forefathers of Western science had imagined.

Multiple modalities, epistemologies and pedagogies must be advanced in STEM classrooms so that the next generation are able to think holistically about problems and be culturally literate as well as scientifically literate (Bang & Medin, 2010; Kawagley, 1995; Maryboy, Begay & Nichols, 2020; Venkatesan et al., 2019). Multicultural educational spaces can be the drivers of innovation that we need for the future (Gutiérrez, Baquedano-López & Tejada, 1999; Venkatesan et al., 2019).

Indigenous scholars have advocated for the inclusion of IWK into STEM education (Kawagley, 1995; Maryboy, Begay & Nichols, 2020; Mason et al., 2012; Venkatesan et al., 2019). In Mason et al. (2012), Indigenous leaders recommended the development of a national curricula for the inclusion of IWK in STEM, tailored for regional differences, along with lasting interpersonal

relationships and partnerships between educational institutions and Tribal communities in the United States. The research carried out in Chapter 2 is one example of a framework for a multicultural STEM curriculum in partnership with Indigenous educators and scholars.

Chapter 3 addressed the cultural roots of state and federal land management in the U.S., and the historic exclusion of local voices including Indigenous stakeholders. Today, we are living in a time where trust in science is diminished in many communities (Cochran et al., 2008; Gauchat, 2012). The inclusion of historically excluded groups and local voices in environmental decision making is vital to restore this trust. Local stakeholders have place-based knowledge that can help to develop nuanced solutions to environmental problems, which vary locally and are not readily solved with the blanket solutions often applied by traditional Western land management approaches (Cochran et al., 2008). The engagement of local stakeholders is important because socio-cultural factors impact the success of management plans at the policy level.

Chapter 4 explored Indigenous advocacy, engagement, and approaches to one of humanity's most pressing environmental problems, climate change. Indigenous communities globally have been incredibly active leaders and participants in environmental movements. This is no surprise given that many Indigenous communities rely heavily on the environment for livelihood, survival and economic, cultural, and spiritual resources. Global leaders need to appropriately engage Indigenous communities on the terms of those communities in developing socially and environmentally just plans to mitigate and address climate change impacts.

Together, these chapters explored some of the arenas that are increasingly important in the environmental realities of today and the future. Education, outreach, stakeholder engagement, and advocacy are necessary to develop sustainable plans for robust and resilient ecosystems going forward.

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