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Why STEM Needs Indigenous Traditional Ecological Knowledge: A Case Study of Ichishkíin Math

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ABSTRACT

In our paper, we discuss the benefits of applying an Indigenous traditional ecological knowledge (TEK) framework to STEM fields. We draw from our shared experiences with feminist praxis and in building an Indigenous TEK Initiative at the University of Oregon. In this paper we focus on a case of how an Indigenous Tribal Elder contributes to our project on Ichishkíin math. We place this project in a broader context of how Tribal Elders are deeply engaged in STEM education and research including: Indigenous language documentation, natural resources management, and traditional Tribal stories that explain how all parts of ecology are relatives. In our paper, we share examples of TEK contributions to STEM and conclude that TEK makes the following impacts in STEM fields: 1) shifts the narrative of who "belongs"; 2) (re)situates Tribal Elders as experts; 3) reclaims Indigenous cultural and language knowledge as inherently important. We urge all STEM researchers, teachers and practitioners to consider the importance of TEK and the vast knowledge and wisdom of Tribal Elders. Doing so subverts the damaging logics that perpetuate exclusionary practices in STEM. All students, scholars, and STEM professionals can benefit from engaging Indigenous Knowledges, and doing so in partnership with Indigenous peoples will have the greatest benefit.

KEYWORDS

TEK, Mathematics, STEM education, Indigenous language

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INTRODUCTION

We write as a collective of scholars with varying experiences with Indigenous Traditional Ecological Knowledge (TEK) research and teaching, and all of us share a deep respect for Indigenous methodologies and feminist praxis. We argue in our paper that engaging TEK is helpful not only for the advancement of Indigenous methodologies within STEM fields, but also for the dismantling of white heteropatriarchy that simultaneously oppresses all peoples and creates barriers for inclusion in STEM. We draw from Indigenous Studies and Indigenous feminist theories to analyze the importance of the case study we present here, as well as to make an argument about how TEK is critical for advancing an intersectional emancipation in STEM fields.

TEK is a broad term that encompasses Indigenous knowledge about the world in which we live, and crosses the disciplinary boundaries found in Western academia, encompassing fields such as biology, geography, math, linguistics, chemistry, history, and economics. Given this interdisciplinary focus, TEK is difficult to define succinctly. However,

> most Native scientists and philosophers agree that TEK originates within and from a particular place, the land and place have taught the people indigenous to that particular region over many generations, and that TEK is the basis for indigenous peoples' languages, cultures, and worldviews (Johnson, 2018, p. 88).

It is important to notice that TEK includes aspects of STEM, and it is impossible to separate these aspects from language and culture. From an Indigenous perspective, STEM is never isolated from fields such as history and literature.

STEM fields remain predominantly, and narrowly, white and male. To diversify, STEM must invite people who identify in other ways, including Indigenous peoples, non-Indigenous women, two-spirit folks, and anyone who challenges the gendered and racial assumptions of who belongs in STEM. This requires STEM education and career pathways be open to change. Diversifying the field matters because "differences in values provide different perspectives on nature, each of which may yield useful insights…diversity in researchers and research perspectives makes for better science" (Medin & Bang, 2014, p. 68).

As scholars who seek to end the racialized and gendered barriers in the academy, we believe it is important to include Indigenous people in STEM education and careers. This is important for Indigenous and non-Indigenous people alike, and it requires a different educational approach to STEM. McCarty and Lee (2014) write that

> education for Native American students is unique in that it implicates not only issues of language, "race"/ethnicity, social class, and other forms of social difference, but also issues of tribal sovereignty: the right of a people to self-government, self-education, and self-determination" (p. 101).

Therefore, when considering STEM education for Indigenous peoples, we must also consider the challenges of colonialism and heteropatriarchy that have oppressed Indigenous peoples, and others, and actively support work to decolonize STEM education. In order for more Indigenous peoples to want to be part of STEM education and careers,

> Native students should have an open and welcoming opportunity to be doubly-educated, to learn Western science without being pressured to assimilate exclusively, or even primarily, into that way of knowing, thinking, and being. In our current society, this gives our Native students a stronger ability to be, and help their communities be, self-determining (Johnson, 2018, p. 91).

Native feminisms focus on the "compound issues of gender, sexuality, race, indigeneity, and nation" (Arvin, Tuck, & Morrill, 2013, p. 11). By attending to these aspects as well as how they interact, and then using this framework to look at STEM, we find a new and different way to look at and think about our educational systems. Native feminist theories and frameworks are important to STEM in that they "offer new and reclaimed ways of thinking through not only how settler colonialism has impacted Indigenous and settler communities, but also how feminist theories can imagine and realize different modes of nationalism and alliances in the future" (Arvin, Tuck, & Morrill, 2013, p. 9). And this, therefore, offers us different possible outcomes. Native feminisms give us a way to critically examine STEM coursework and careers with a hopeful view for the future.

Our case study shows Indigenous students and collaborators that they and their cultural knowledges have a place within STEM education. It also invites newcomers to experience and know valuable Indigenous TEK contributions.

Ichishkíin Mathematics Project Case Study

The Ichishkíin Mathematics Project was born from one person's desire to create curriculum for an Indigenous elementary immersion school. Ichishkíin is a language of the Yakama people who live in what is now known as the Columbia River Plateau in the Pacific Northwest of the United States. Ninety percent of their homelands were forcefully taken by the federal government in the 1855 Treaty process. These stolen lands encompassed roughly one-third of what is now known as the state of Washington. Like many Indigenous languages, Ichishkíin (pronounced Each-ish-keen) was suppressed through colonization and attempted eradication of cultures. Once threatened with extinction, Ichishkíin lives on, nourished by cultural and language reclamation and revitalization projects.

Ichishkíin is the only Native American Indigenous language taught at the University of Oregon throughout the academic year. Through the work of Yakama Tribal Elder, Dr. Virginia Beavert, and her students and apprentices, two full years are offered for college credit with a third year of curriculum currently being planned. Keith Walker is one education student who studies Ichishkíin at the University of Oregon. While a student in Jennifer Ruef's elementary mathematics education classes, Keith translated all course materials into Ichishkíin. Thus began the Ichishkíin Mathematics Project. One of Keith's first challenges arose from translation--not all mathematical words translated directly to Ichishkíin, and not all Ichishkíin words directly translate to mathematical contexts. This is neither surprising nor inherently problematic, except for this: language embodies identity and culture. Creating new language to reflect mathematical concepts requires care and consideration lest the process become yet another form of colonization. Adapting and adopting Ichishkíin calls for collaboration with a cultural and linguistic authority, and consultation with a Tribal Elder and language revitalization leader is both appropriate and respectful.

Mathematics is often framed as culture-free, as the "language of the universe" (c.f., Strogatz, 2019). Mathematics may describe natural phenomena, but it is hardly universal. What we know as mathematics is a set of agreements between humans. The meanings for operations, symbols, and definitions are proposed, debated, and developed over time. Not all mathematical conventions are universally agreed upon. For example, trapezium means very different things (a trapezoid with at least two parallel sides or quadrilateral with no parallel sides) depending on where you pledge your mathematical allegiance: North America or the rest of the world. It is also true that mathematics functions as a cultural space with virtual gates that admit or deny participants on the basis of gender, class, and race. Mathematical cultures often function as white and male supremacies (Gutiérrez, 2017). This matters. Unchecked, mathematics readily becomes a colonizing force. For these reasons, our work intentionally centers Ichishkíin language and Yakama cultural contexts. Mathematics is metaphorically invited into that circle.

Because our work in creating new curriculum calls for the creation of new language, the words that do not translate, our research group encompasses multiple perspectives. A vitally important perspective is that of Yakama Elder and native Ichishkíin speaker, provided by Dr. Virginia Beavert, known to her students as Tuxámshish, who holds a PhD in linguistics. Keith Walker is also a linguist, and learner of both Ichishkíin and elementary mathematics teaching methods. Michelle Jacob is a scholar of Indigenous education--the center of our network, she facilitates our conversations. Jennifer Ruef offers her perspective as a mathematics education researcher. Joana Jansen is research faculty at UO and a linguist who studies and develops curriculum with Tuxámshish and wrote a grammar of Yakama Ichishkíin. Stephany RunningHawk Johnson is a doctoral candidate in the Department of Education Studies with expertise in TEK and STEM education.

In a nutshell, here is how the case study works: In practice, Keith proposes mathematical concepts and possible Ichishkíin words to describe them. These are written by hand or typed, and then taken to Virginia’s house where we meet,

socialize, and work according to the pace that Virginia prefers. Virginia vets the words and work done by Keith and sometimes proposes alternatives. Michelle interviews Virginia to prompt her stories of how particular mathematical contexts are present in Yakama lived experiences, historically, and/or in contemporary times, sometimes drawing from her own experiences or relating experiences of family members. Jennifer helps frame these contexts in terms of commonly agreed upon mathematical ideas. Joana draws from linguistics to help shape word or concept structure and spelling using the orthography and grammar that she has helped to shape with Virginia for Ichishkíin. Collectively, slowly, intentionally, Keith's goal of crafting an Ichishkíin immersion curriculum for elementary mathematics takes shape. Together we discuss mathematical concepts and language. Stephany adds insights from TEK and Indigenous STEM education literatures, and from her own experience as an Indigenous secondary math and science teacher.

The group may work on the meaning of the term "fraction," and find or craft Ichishkíin language to represent those concepts and meanings. We consider such questions as: Where do fractions exist? In the folding of paper to create equal sized partitions? In the breaking of larger sets of things into smaller, equally sized subsets? In the division of one number by another? As a ratio of one thing to another? In arranging teepee poles and stakes around the perimeter of the teepee? In portioning roots to be dried and to be given immediately to others? In properly packing a horse’s burden? All these concepts are part of the bigger idea of what it means for a number to be a fraction. Finding connections between Yakama culture and mathematical culture is a starting point for discussions about how to name them in Ichishkíin.

This work is rich and interesting, bringing together diverse fields and centering Indigenous Tribal Elder knowledge. Through this work, mathematics can be reclaimed as an academic space that honors TEK and makes space for Indigenous peoples and cultures. Our case study draws inspiration from the argument that schools should be “sacred landscapes” shaped by Indigenous knowledge systems (Garcia & Shirley, 2012). Education is always sustaining culture in one way or another, and we see how STEM education in particular is dominated by white heteropatriarchal culture. However, we agree with San Pedro’s questioning “whose knowledges, languages, and literacies are deemed worthy of inclusion in schools” (San Pedro, 2018, p. 334). Our case study addressed this question by examining how math curricula is not value- or culture-free, and we purposefully engaged math in a process that centered Ichishkíin and Yakama Indigenous cultural teachings.

We view our project as supporting the central focus of decolonizing methodologies, which asserts that research should contribute to Indigenous self-determination (Smith, 2012). However, we understand that a case such as ours must be sustained over the long-term to make a larger impact. One the one hand, we have been changed by this work. Placing Indigenous language and cultural knowledge at the center of our project, in collaboration with an Indigenous Elder shifts the ways in which we view authority, knowledge production, and curricular questions. We see

in the project how Elder pedagogy models the virtues honored in Yakama culture (Wilkins, 2008).

Yet, we are also cognizant of the ways in which settler colonial education, rooted in exclusionary systems of white heteropatriarchy continues to enforce STEM fields as gendered and racialized spaces. We are aware, even as we work on this case study to support Indigenous math, that to earn their teaching licenses our students are evaluated and must continue to abide by the settler state rules for demonstrating content knowledge such as reaching specific cut scores on standardized tests.

Our vision of education, as described in the case study, stands in contrast to the mainstream ways of being and knowing in STEM fields. We agree with Lambe (2003), who articulates, "with Indigenous education, I have found that what constitutes validity is very different than mainstream education" (p. 308). While we are making important contributions by connecting Indigenous knowledges with math education, our case study further highlights the need for STEM educators to engage in resistance in settler colonial institutions (Tuck & Yang, 2012). We must grow the movement to re-center Indigenous knowledges across fields in education, and in STEM fields more broadly. This means that STEM needs to embrace not only TEK as important for knowledge content, but rather to also shape methodological approaches. Collaboration is key, as we have found in our case study. We agree that "the concept of TEK should be understood as a collaborative concept. It serves to invite diverse populations to continually learn from one another about how each approaches the very questions of 'knowledge' in the first place" (Whyte, 2013, p. 2).

Innovation

STEM and Language Revitalization (LR) practitioners have started to see the benefits of collaboration in Indigenous language documentation and use, resource management, and curriculum development. Yakama Elders, for example, have stressed that the best management of natural and cultural resources depends on understanding the resources' history and significance through the Ichishkíin language, as English is not an adequate representation (Jacob, 2009; Jansen et al., 2018). Place-based educational approaches, used in language and STEM classrooms, link students to their lived experiences and environments and are compelling to students (Jansen, Underriner, & Jacob, 2013). Indigenous TEK links to science, the environment and natural world are more straightforwardly integrated into a typical U.S. classroom and satisfy state education standards. This relative ease extends to TEK and LR. In many cases, terms in Indigenous languages and the dominant language of that place have a fairly clear (though not necessarily 1:1) correspondence, as in Yakama Ichishkíin wána '*river*'; hulí *'wind'*; wawachí '*acorn*'.

In the work we describe and pursue here, we find that, as discussed above, mathematics and mathematics concepts are much more difficult to translate and apply although work has begun (see Kalish, 2007; Kaomea 2011; Kukahiko 2014; & Lipka et al., 2005 for examples in Diné, Hawaiian, and Alaska Native language contexts). Category terms such as 'algebra' and 'geometry' are learned from

studying mathematics in the classroom; they do not exist in Yakama Ichishkíin. Linguists who describe Indigenous languages may not recognize how mathematical concepts are expressed within the language, and depending on how they themselves experienced mathematics, may think of mathematics as an abstract, cognitive pursuit, not something that is grounded in our experience of the world. If a language has no word for square, Elders can determine a translation (such as 'has four equal sides and four right angles') but a more authentic way to teach the concept could arise through the patterns on a woven wápaas (*'root/berry basket'*). The challenge and innovation are to determine how to go beyond translation and build a math curriculum from the culture and in the language. This is one example.

A challenge going forward in producing mathematics curriculum for Ichishkíin is to match the language level of the mathematics curriculum with the language fluency of the students in an elementary immersion classroom. Most students do not have robust access to the language at home and describing things like relations and processes is complex in any language. Asking a student to answer "How did you get to this number?" is beyond current fluency levels. Additionally, as language is created for different concepts, this new language is not necessarily shared across Elders or classrooms. While we do not want to impose one 'right' way of talking about numbers, we also want students to feel comfortable and confident using the words they have learned.

The language incorporated into the Ichishkíin Mathematics Project relies on what is traditionally women's knowledge and women's language in the culture.
While Ichishkíin does not have a separate vocabulary for males and females, realms such as food gathering, weaving, and shelter represent women's roles and activities and embody mathematical concepts for our teacher, Tuxámshish. This serves to broaden the narrative within mathematics and STEM of who belongs and who the experts are

A further innovation of this work is that it reclaims women's important roles as educators and leaders, which is sorely needed in STEM fields and in STEM education. In our other work, we describe how women's leadership is crucial for infusing cultural teachings into educational efforts that serve Indigenous peoples broadly and provide important place-based educational models for all peoples. We view such efforts as decolonizing education, and believe that STEM can benefit from this approach, as we state elsewhere, "a central tenet of Yakama decolonizing praxis is that women are important as culture bearers and teachers" (Jacob, 2013, p. 108). Such work is crucial not only out of feminist concerns, which we hold, but also because having a gendered leadership balance is crucial for restoring Indigenous ways of making sense of the world. As we write elsewhere,

> [a]cross the examples of Yakama decolonizing praxis is an understanding that our people are healthy when we build movements with a gendered balance. This lesson is deeply rooted in traditional Yakama spirituality" (Jacob, 2013, p. 110).

Currently, in our STEM classrooms and career fields, we see a large imbalance in gender and gender roles. This is problematic for Indigenous and non-Indigenous people alike, and using a Native feminist analysis and TEK provides a pathway to begin to address these issues and bring about a more balanced state.

Impact

Engaging TEK and Indigenous knowledges in knowledge production and methodological processes used in STEM fields is critical. We have witnessed the ways in which TEK brings diverse fields of knowing together that might otherwise be siloed from one another in the academy. For example, this paper has bridged the divides between our home fields of study: mathematics education, sociology, science education, and linguistics. What unites us, and the STEM inquiry underlying our paper, is our respect for TEK, our partnership with an Indigenous Elder, and our engagement with Indigenous knowledges. We focus on one case of Ichishkíin mathematics, to illustrate the benefits of TEK for STEM fields. Our case study is successful in terms of Indigenous and decolonizing methodologies of building and respecting relationships and honoring Indigenous knowledges.

Research has also been a form of colonization (Paris & Winn, 2013; Smith, 2018). Rather than 'doing research' on an Indigenous community, we focus on working with and for our Yakama Elders and community. Our research choices are driven by the priorities expressed by our Yakama collaborators. We consider carefully the effects of our work and writing. Our goal is a mutually transformative partnership, a model we wish to share with other researchers.

We still work within a colonial system. We recognize that, too often, Elders are often neither recognized nor compensated for their work. We all must ask ourselves how we can ethically and responsibly approach Elders and communities, as well as seriously pursue recognition for the invaluable work done by speakers of Indigenous languages. Recognition for this work can include monetary compensation, co-authorship on papers, and support of academic and scholarly goals, although this is just the beginning of what might be appropriate for different communities. For example, Tuxámshish is a mentor to many students, staff, and faculty at our home academic institution, and she is a paid collaborator on grants and has a portion of her time paid for through her position at the university as Distinguished Elder Educator, a position that was created two years ago to address the concerns we are raising here. She was supported in her goal to come to the University to earn her PhD degree and to teach her language here. While such examples are not sufficient, and Tuxámshish always gives more than she receives, we strive to continue to find ways to disrupt the colonial legacy of researchers "taking" from Indigenous communities generally, and Elders in particular.

Our work on the Ichishkíin Mathematics Project is in its early days and we have much to learn about the ways Yakama people live mathematically. The language gives us information about additional areas to focus on. For example, there is a basic, non-human set of numbers, and a second set used when referring to humans (niipt *'two'*, nápu *'two humans'*). Specific number suffixes indicate the number of times something has occurred and inclusivity: nápaam *'twice'*, níiptik *'both (non-*

human)', nápwak *'both (human)'*. The etymologies of numbers are important: *túskaas*, the number seven, is related to the instrumental prefix *tux̲s-* 'with pointed end', and refers to the seventh or index finger, as that is the seventh finger reached when counting on one's hands starting with the thumbs. Lifeways also direct us, and we look to related research projects that share the ways Indigenous peoples developed systems of navigation, agriculture, aquaculture, and the use of fire and water before these were recognized or developed by Western societies (e.g., Pascoe 2014; Langston). What other mathematical systems have yet to be recognized and honored? In addition, although our work to date has been with Elders who identify as women, future explorations can include the contributions of two-spirit folks.

Our case provides important insight into the ways in which mathematical concepts are expressed and lived in Ichishkíin and Yakama Indigenous culture. This project has helped us to see mathematics in a different light. Mathematics classrooms, curricula, and pedagogies can be places that honor, respect, and include Indigenous knowledges, as we have begun to do with this case study. We have more to do, however. Our case study is only the beginning of what we hope will be widespread transformation of how Indigenous knowledges and TEK will be engaged in higher education and throughout settler colonial society. Overwhelmingly, mathematics curricula, classrooms, standardized tests, and pedagogies continue to perpetuate settler society cultural norms of heteropatriarchal whiteness, which typically assume that Indigenous knowledges either do not exist, or do not have much to contribute to STEM. We will continue the work of this case study, as well as share our experiences and findings in order to disrupt this harmful practice that is so common in education and STEM fields. In doing so, we affirm both the Indigenous and the feminist right to engage, and contribute to, STEM.

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