An Instructor's Guide to Including Traditional Ecological Knowledge in the Undergraduate Biology Classroom

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ABSTRACT

Indigenous students are underrepresented in science, and the exclusion of Indigenous knowledge from Western education may be a contributor. Recently, Indigenous and non-Indigenous researchers have called for a better integration of Indigenous knowledge systems into Western science. One suggestion from the literature is to integrate Traditional Ecological Knowledge (TEK), or the diverse intimate knowledges and practices that relate to the environment that are commonly held by Indigenous peoples around the world, into our classrooms. However, this approach can be daunting and unfamiliar for undergraduate biology instructors, and they may be hesitant to attempt to include TEK in their classrooms. In this essay, we summarize practical suggestions and caution from the literature on how to include TEK in biology courses for instructors who are interested in increasing Indigenous student belonging using this approach. Suggestions include exploring other ways of knowing, teaching holistically, establishing a classroom culture of respect, explicitly including TEK, consulting Indigenous experts, incorporating Indigenous languages, and using other evidence-based teaching practices. Implementing these practices in biology classrooms may be messy, but engaging in this difficult process is important as we strive for more inclusivity in biology education. We end the essay with suggestions for future research.

INTRODUCTION

Indigenous Representation in STEM

When looking at the persistence of different groups in science, technology, engineering, and math (STEM), disparities in representation emerge the farther one goes up the scientific academic ladder, a phenomenon termed "the leaky pipeline." Although the leaky pipeline idea originated with gender disparities in STEM (Pell, 1996; Blickenstaff, 2005), it has also been used to describe the attrition of PEERs, or persons excluded because of their ethnicity or race (Barr *et al.*, 2008; James *et al.*, 2012; Asai, 2020). PEERs, including persons of Indigenous descent, often have high initial interest in science yet leave science at higher rates than non-PEERs (Huang, 2000; Asai, 2020). This has been recognized as a problem for decades, as a lack of diversity in science curbs creativity, innovation, and our ability to adapt to a changing world (Kimmerer, 2002; Page, 2008; Asai, 2020). Efforts to increase diversity in the science workforce have not been entirely successful, so work is still needed (Science, 1992; Valantine and Collins, 2015; Liu *et al.*, 2019). In this essay, we focus specifically on Indigenous populations, using the term "Indigenous" to describe persons of Native American, American Indian, Alaskan Native, Aboriginal, First Nation, Native Hawaiian, or Pacific Islander descent.

While various Indigenous groups are among the most underrepresented ethnic groups in STEM, their exclusion is often unacknowledged and not quantified (Kerr *et al.*, 2018). The extent of Native Hawaiian and Pacific Islander (NHPI) exclusion has often been overlooked, as their demographics are commonly included with Asians in

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federal agency initiatives (Kerr *et al.*, 2018), but more recent data separating NHPI from Asians are available and highlight the disparities in educational attainment for Indigenous students. Based on the 2019 U.S. Census Bureau's American Community Survey (www.census.gov/programs-surveys/acs/microdata.html), only 4.1% of Native Hawaiians, 4.5% of Pacific Islanders, and 4.7% of American Indians or Alaska Natives (AIAN) had earned a graduate or professional degree compared with 9.2% of whites, 16.3% of Asians, and 5.6% of Blacks. From the National Center for Education Statistics Integrated Postsecondary Education Data System (https://nces.ed.gov/ipeds/use-the-data), we see that only 42% of AIAN and 52.7% of NHPI seeking a bachelor's degree had graduated (as of August 31, 2020) compared with 67.8% of white students.

In terms of science degrees specifically, the small numbers of Indigenous students make the extent of exclusion difficult to interpret. In the most recent data available, AIAN made up 0.79% of the U.S. population (ages 18–44), but only accounted for 0.45% of bachelor's degrees, 0.49% of master's degrees, and 0.38% of doctoral degrees awarded (National Center for Science and Engineering Statistics, 2021). NHPI accounted for 0.21% of the U.S. population (ages 18–44), and although they were represented in bachelor's and master's programs (i.e., 0.22% of science bachelor's degrees and 0.22% of master's degrees that year), they were underrepresented in doctoral degrees, only accounting for 0.14% of science doctoral degrees (National Center for Science and Engineering Statistics, 2021). In Canada, Aboriginal students have been shown to be underrepresented in science, with only between 8 and 14% of students of Aboriginal ancestry enrolling in 12th-grade biology (Snively and Williams, 2008).

The low numbers of Indigenous people in STEM may be attributed to the exclusionary culture linked to Western science's colonial roots (Akena, 2012; Reyhner, 2017; Asai, 2020). Colonization has negatively impacted Indigenous peoples throughout the world as attempts were made to erase and assimilate their cultures into the dominating culture of the Western world (Hewson and Ogunniyi, 2011; Howard and Kern, 2019b). Historically, Westerners labeled Indigenous cultures as inferior and tried to weed these cultures out of society, perpetuating the idea that Native cultures were primitive or undesirable (Kim, 2015; Reyhner, 2017). This has resulted in an educational environment that continues to exclude and devalue Indigenous cultures and knowledge systems, many of which were in existence long before Western science (Smythe and Cady, 2009; Hewson and Ogunniyi, 2011; Vallée, 2018). Additionally, omitting Indigenous knowledge from our classrooms perpetuates cognitive imperialism, wherein Eurocentric knowledge is heralded as the most important way of knowing and others are deemed as inferior or lower status (Hewson and Ogunniyi, 2011; Sparkes and Piercey, 2015; Vallée, 2018; Fildes *et al.*, 2021).

The repercussions of exclusion can extend to Indigenous students' performance on exams and other measures considered the success standard from the Western perspective, which in turn may impact their access to future opportunities. In the United States, Native American students test below average and have lower graduation rates than their peers (Reyhner, 2017), and in British Columbia, Indigenous students have lower rates of academic success (Ignas, 2004). Indigenous high school students in Australia had lower science literacy and performance than their non-Indigenous peers, even though they were equally interested in science (McConney *et al.*, 2011). This trend was also found among Indigenous students in New Zealand, with studies finding that Māori and Pasifika students had lower achievement scores in science compared with their non-Native peers (Waiti and Hipkins, 2002; Kidman *et al.*, 2011). These alarming trends likely result from education systems failing Indigenous students. In 2003, the U.S. Commission on Civil Rights reported that Native American students were not afforded equal educational opportunities to other American students, citing "deteriorating school facilities, underpaid teachers, weak curricula, discriminatory treatment, and outdated learning tools" (U.S. Commission on Civil Rights, 2003; Barnhardt and Kawagley, 2005). They also pointed out that Native cultures, histories, and practices were largely absent from their leaning environments, and attributed the achievement gap faced by Indigenous students to this exclusion (U.S. Commission on Civil Rights, 2003; Barnhardt and Kawagley, 2005).

Purpose of this Essay

To counteract the exclusion of Indigenous students in science, we can consider ways to increase the sense of belonging of Indigenous students in our classrooms. One method that has been proposed is the integration of Indigenous Knowledge Systems (IKS), particularly Traditional Ecological Knowledge (TEK), into biology classrooms (IKS and TEK are disucssed in more detail later in the paper; Kimmerer, 2002; Armstrong *et al.*, 2007; Schmidt and Stricker, 2010; McCarter and Gavin, 2011; McConney *et al.*, 2011; Musante, 2014; Nalau *et al.*, 2018).

Previous reviews include discussions of TEK in the context of sustainability research (Lam *et al.*, 2020), sustainability education (Zidny *et al.*, 2020), forest management (Cheveau *et al.*, 2008), conservation initiatives (Benyei *et al.*, 2020), and marine environmental science (Thornton and Scheer, 2012). In this essay, we aim to discuss the incorporation of TEK in undergraduate biology education broadly. We summarize and analyze the literature regarding best practices when including TEK in the undergraduate biology classroom, propose ideas to implement these practices, and evaluate the limited data on how such incorporation affects students. Additionally, we offer suggestions on what is missing from the literature, areas where non-Indigenous instructors may need more guidance from Indigenous stakeholders, and ideas for the focus of future research.

Author Positionality

We are non-Indigenous women and educators who hold or are working toward advanced degrees in science, and we are discipline-based education researchers who focus on inclusive practices in undergraduate biology education. We are looking at the literature through the lens of white women who have a strong desire to better serve our Indigenous students yet have serious fears of doing this inappropriately or offensively. Thus, as we read articles, we are hungry to find practical suggestions and explicit dos and don'ts that we can use for guidance. In this essay, we aim to synthesize the literature from experts in Indigenous ways of knowing and summarize those practical suggestions for other non-Indigenous undergraduate biology instructors.

Our background has benefits, as it equips us to understand other educators who share our non-Indigenous identity, have a strong desire to be more culturally competent, and may be afraid to take steps in case they misstep. Our experience in the classroom, including time spent teaching NHPI students at a university in Hawaii, gives us personal experience to draw upon as we imagine ways to implement the suggestions given in the literature. As non-Indigenous faculty vastly outnumber Indigenous faculty (National Center for Educational Statistics, 2020), future widespread change in STEM education will likely need to involve non-Indigenous instructors and researchers. Thus, our intent is to engage our peers in discussion on Indigenous exclusion and how we can start now in small ways to shift Western science culture away from cognitive imperialism.

Our lens also has weaknesses that greatly limit the potential impact of our work, as our interpretations of the literature are inherently formulated from a position of privilege within a Western science epistemological framework. By desiring to focus on practical suggestions that will inspire educators to start with small steps, we may oversimplify issues or cross over into appropriation. The articles we have read include long discussions of this danger and ways to avoid it, so we lean heavily into their words to try to avoid this. However, we recognize that we may do so despite good intentions. Ultimately, Indigenous instructors and researchers are the best equipped to comment on the appropriate integration of Indigenous knowledge and Western science, and many have already done so. We hope to amplify their voices in this essay as well as invite further critiques and conversation regarding our work.

What Are Indigenous Knowledge Systems and Traditional Ecological Knowledge?

Indigenous Knowledge Systems (IKS). In the literature, IKS refers to the numerous ways of knowing found in Indigenous cultures around the world that exist outside a Western framework. IKS encompasses the practices and knowledge of Indigenous peoples that arose before colonialism, often through intimate relationships with the natural world, and that are still used today to economically, socially, and spiritually sustain millions of people (De Beer and Whitlock, 2009; Quigley, 2009; Smythe and Cady, 2009; Hewson and Ogunniyi, 2011). IKS are as diverse as the Indigenous peoples who hold them, but a unifying theme is that IKS are part of "cultural system[s] that [encompass] native languages, naming and classification systems, use of resources, rituals, spirituality, and worldviews" (Quigley, 2009, p. 79). IKS contribute to their communities; serve their people; and are continually being used, challenged, and adapted (Gorjestani, 2000; Quigley, 2009). Aside from the Indigenous people who originate IKS, academic, nonprofit, and governmental programs are increasingly interested in IKS to inform Western science, empower Indigenous communities, and protect Indigenous intellectual property rights (Gorjestani, 2000; Aikenhead, 2002; Quigley, 2009; Verma *et al.*, 2016).

For this review, we will use "IKS" when referring to broader Indigenous knowledge systems that do not necessarily need to be related to the Western worldview of science. We emphasize that IKS are diverse and not necessarily homogenous (Acton *et al.*, 2017), but we discuss them as a group, as all are generally excluded from Western education.

Traditional Ecological Knowledge (TEK). The literature frequently defines TEK as the knowledges, experiences, practices, and intimate understandings of the environment that humans have acquired over thousands of years, often found in Indigenous cultures worldwide (Berkes, 1993; Snively and Corsiglia, 2001; Kimmerer, 2002; Smythe and Cady, 2009; Hewson and Ogunniyi, 2011). Thus, TEK would be considered specialized knowledge systems within IKS that are specific to localized ecological knowledge (Quigley, 2009). Most definitions of TEK also describe it as knowledges and practices that are inherently laden with values, such as reciprocity between the human and nonhuman world, responsibility for all living things, and respect for the Earth (Kimmerer, 2002; Smythe and Cady, 2009). This is further supported by McGregor's definition of TEK as "the process of *participating* fully and responsibly in [the relationships between knowledge, people, and all Creation (the 'natural' world as well as the spiritual)], rather than specifically as the knowledge gained from such experiences" (McGregor, 2004a,b, 2008, p. 145; Whyte, 2013). McGregor further explains that "For Aboriginal people, TEK is not just about understanding relationships, it *is* the relationship with Creation. TEK is something one *does*" (McGregor, 2004a,b, 2008, pp. 145–146; Whyte, 2013). TEK is distinct and varied amongst Indigenous peoples around the world–as a term it refers to the *many* diverse knowledges and practices that are held by Indigenous peoples, not to one universal "Indigenous knowledge" (Grant, 2013).

Sometimes those who are defining TEK are non-Indigenous scholars or professionals who may tend to privilege their own agendas in their definitions, spurring controversy around the term (Whyte, 2013). However, Indigenous scholars have also spoken of TEK and called for its recognition as a valid and important source of knowledge (e.g., Kimmerer, 2002) and elaborated on how TEK is best understood (e.g., Whyte, 2013). Whyte argues that TEK should be understood as a collaborative concept that encourages diverse groups to learn from one another and hopefully blend knowledge to enhance our ability to be stewards over the Earth and adapt to challenges such as climate change (Whyte, 2013).

Examples of TEK have been referenced in scientific and political realms, including detailed histories of biological species, populations, communities, and ecosystems; the monitoring and sustainable harvesting of resources; climate patterns; ethnotaxonomy and ethnobotany; and the management and manipulation of disturbance regimes, to name a few (Berkes, 1999; Kimmerer, 2002). Some examples of TEK are historical, such as the ancient practice of creating forest islands to increase fruit production and attract game (Gadgil *et al.*, 1993; Whyte, 2013), while others are traditions still practiced today, such as deer cleaning (Reo and Whyte, 2012; Whyte, 2013) or caribou hunting techniques (Barnhardt and Kawagley, 2005) that incorporate community values. Many examples of TEK (e.g., burning practices; observations of fluctuations in water levels, sea ice, and lake processes; and the movements of animal populations) have practical applications in natural resource management and climate change research (Kimmerer and Lake, 2001; Eisner *et al.*, 2009; Voggesser, 2010a,b; Wildcat, 2009; Nakashima *et al.*, 2012; Whyte, 2013).

Highlighting Indigenous Knowledge in STEM

Benefits for Indigenous Students.

The majority of the literature we were able to find enthusiastically calls for the incorporation of TEK in science courses (Garrison, 1994; Snively and Corsiglia, 2001; Snively and Williams, 2005, 2008; Kimmerer, 2002, 2012, 2013b; Michie, 2002; Feinstein, 2004, 2005; Barnhardt and Kawagley, 2005; Schroder, 2006, 2008; Armstrong *et al.*, 2007; Le Grange, 2007; De Beer and Whitlock, 2009; De Beer and Petersen, 2017; Kellogg *et al.*, 2010; Schmidt and Stricker, 2010; McConney *et al.*, 2011; Mack *et al.*, 2012; Rich, 2012; Acton *et al.*, 2017; Fonua, 2018; Zidny and Eilks, 2018; Zidny *et al.*, 2020; Albuquerque *et al.*, 2021; Archila *et al.*, 2021; Fildes *et al.*, 2021; Robinson *et al.*, 2021). As Indigenous students have been shown to have similar levels of interest in science as non-Indigenous students (Huang, 2000; Asai, 2020), the incorporation of TEK in Western science has been described as a "significant avenue of opportunity for engaging Indigenous students" (McConney *et al.*, 2011). It is well known that belonging is important for success in education (Osterman, 2000; Korpershoek *et al.*, 2020; Chen *et al.*, 2021), and students' belonging and achievement increase when they identify with the material and values being taught (Davison and Miller, 1998). If Indigenous students are not identifying with the values taught in science classrooms, science curricula can be adjusted to incorporate material and highlight values that are more meaningful to Indigenous students (Kimmerer, 2002; Michie, 2002). When differences between Indigenous cultures and the philosophy of Western science are emphasized, belonging of Indigenous students is likely to decrease (Zidny *et al.*, 2020). Admittedly, there are differences between Western science culture and Indigenous cultures; however, there are similarities that, when highlighted, can convey to students that the two cultural frameworks are compatible (Kimmerer, 2002; Johnson *et al.*, 2014). Student engagement also increases when students perceive that what they are learning is relevant to their lives (Zidny *et al.*, 2020). Thus, if identifying with the values of science is this critical to student belonging, it is important that we, as science instructors, highlight the compatibility of Indigenous and Western values to increase the representation of Indigenous students in STEM (Michie, 2002).

Benefits for Non-Indigenous Students and the Field. The literature also highlights four ways that non-Indigenous students and STEM fields overall may benefit from the inclusion of TEK in science classrooms. First, awareness of TEK presents non-Indigenous students and scientists with knowledge that can help solve critical environmental issues. Many Indigenous cultures are rooted in sustainable living with a highly refined awareness of the environment, making them important stakeholders in the land's conservation and biodiversity (Berkes, 1993; Gadgil *et al.*, 1993; Kimmerer, 2013b). The cultivation and practice of TEK in Indigenous homelands has led to Indigenous lands holding some of the highest remaining biodiversity on the planet (Durning, 1992; Kimmerer, 2002; Smythe and Cady, 2009; Molnar and Babai, 2021). Thus, TEK is being increasingly sought after by academics, scientists, and policy makers as the inherent value it possesses in the fields of ecosystem management, conservation biology, climate change, wildlife sustainability, and ecological restoration is recognized (Kimmerer, 2002; Schmidt and Stricker, 2010; Kidman *et al.*, 2011; Rich, 2012; Nalau *et al.*, 2018; Robinson *et al.*, 2021). In the United States, TEK was formally recognized by the federal government in November 2021 as an important body of knowledge that should inform decision making (U.S. Office of the Press Secretary, 2021).

Second, including TEK in science education curricula could also help students understand the importance of weighing cultural considerations when making conservation management decisions, a skill that is needed in the science workforce (Schmidt and Stricker, 2010). There is a need to educate students on methods of conservation that are people-friendly, participatory, and community based so that Indigenous approaches are not marginalized or disregarded (Siebert and Belsky, 2007). Including TEK in mainstream academia can thus help conserve the heritage of Indigenous peoples and revitalize Indigenous cultures while promoting conservation of the environment (McCarter and Gavin, 2011; Cocks *et al.*, 2012).

Third, TEK's belief that humans play an important role in ecosystems is congruent with the core concept of systems thinking included in the *Vision and Change* report (American Association for the Advancement of Science [AAAS], 2011) and highlights an area where TEK can enhance learning for all students. TEK's emphasis that humans are not above nature may help reform students' misconceptions concerning human exceptionalism that are characteristic of the anthropocentric thinking that can sometimes be found in Western culture (Coley, 2007; Pickering, 2008; Betz *et al.*, 2019).

Fourth, aside from specific benefits of the knowledge found in TEK itself, some have suggested that including TEK in STEM classes helps dismantle the stereotypical nature of science as being for white men, which would benefit all types of diverse students, not just Indigenous students (Ruef *et al.*, 2020). Thus, "[incorporating] TEK into science curricula not only broadens the horizons of students from the dominant culture but also can validate and encourage the inclusion of native students" (Kimmerer, 2002, p. 435).

Dangers of Incorporating TEK into Biology Education. Although much of the literature cites the benefits of incorporating TEK into biology education, there are others who oppose the integration of the two knowledge systems. A review by Kim *et al.* (2017) argued that the incorporation of TEK into biology education is cultural and intellectual appropriation, citing literature that asserts TEK is an attempt to distill IKS down to ideologies that fit within and support Western science viewpoints. Because TEK has been conceptualized within a Western science framework and is thus "packaged" to fit within a Western perspective, this can lead to the misrepresentation and misinterpretation of IKS (Simpson, 1999; Aikenhead, 2002). Furthermore, when practices and knowledge of Indigenous peoples are singled out and conceptualized as TEK within a non-Indigenous framework, the practices and knowledges can take on new meaning with different implications in their new setting (Kim *et al.*, 2017). Finally, some have argued that compartmentalizing TEK to fit within Western science disrespectfully assumes that the lives and experiences of Indigenous peoples can be compartmentalized (Nadasdy, 1999). These warnings are important and should be carefully considered by anyone thinking of including TEK in the classroom.

Weighing the Dangers and Benefits. As noted, there are conflicting perspectives on whether TEK, as a concept, is appropriate or ethical and whether it can be respectfully discussed in Western science contexts. We acknowledge that these counterpoints are valid and concerning: There is a risk of appropriating and/or compartmentalizing Indigenous knowledge when trying to include TEK in biology education. After considering and engaging with these counterpoints, we feel that not including TEK for those reasons risks perpetuating Indigenous erasure in academia. However, although we argue for the inclusion of TEK in science classes, we carefully consider the dangers and present practical suggestions for avoiding appropriation and tokenization. We also encourage instructors not to ignore these counterpoints and suggest they openly acknowledge the complexity of this issue with their students as they move forward.

Many educators may be interested in joining the movement to decolonize academia but are stopped by a paralyzing fear of appropriating and/or misrepresenting Indigenous voices in their classes. Ultimately, incorporating TEK and Indigenous voices in science classes will likely be messy and will require humility, patience, and course corrections. Our hope is that these suggestions will be helpful to university biology instructors who are looking to thoughtfully increase inclusion in their classrooms. While taking small steps to include TEK in our classrooms should not be the end goal of working toward equity and inclusion for Indigenous students, it may provide a good foundation for future work.

SUGGESTIONS FOR THOUGHTFULLY INCLUDING TEK IN BIOLOGY CLASSROOMS

We synthesized recommendations on ways to integrate TEK into biology classrooms from both theoretical and evidence-based articles. Table 1 summarizes suggestions for instructors for making biology classrooms more inclusive for Indigenous students, and Table 2 summarizes practices to avoid. We then highlight these various approaches in more depth.

Explore Other Ways of Knowing

Typically, *science* education does not include ways of knowing that exist outside the framework of Western science, which involves the systematic building of knowledge through testable predictions and is rooted in reductionism, reason, and rationality (Acton *et al.*, 2017). However, we can do better at acknowledging that there are many ways that people understand, organize, and interact with the world (Garrison, 1994; Nelson-Barber and Estrin, 1995; Barnhardt *et al.*, 1998; Tsuji and Ho, 2002; El-Hani and de Ferreira Bandeira, 2008; Mack *et al.*, 2012; Acton *et al.*, 2017; Howard and Kern, 2019a). IKS are powerful and legitimate ways of knowing that can be relevant to biology education (Garrison, 1994; Barnhardt *et al.*, 1998; Kimmerer, 2002, 2013a; Tsuji and Ho, 2002; Appanna, 2011; Mack *et al.*, 2012), but they are often marginalized under Western dominant culture, which has adopted Western science as the bar for knowledge and "truth" (Shizha, 2007; Smythe and Cady, 2009; Howard and Kern, 2019a; Albuquerque *et al.*, 2021). Educators can respectfully acknowledge that Western science is not the only way that people know about the world, nor the only *correct* way (Garrison, 1994; Nelson-Barber and Estrin, 1995; Barnhardt *et al.*, 1998; Smythe and Cady, 2009; Acton *et al.*, 2017). The natural world is sometimes portrayed differently in Western science and IKS (Medina-Jerez, 2008; Mack *et al.*, 2012), which can alienate Indigenous students and cause them to feel conflict between their cultural values and what they are learning (Lee, 2001; Kimmerer, 2002; Appanna, 2011). If instructors ignore other ways of knowing in their science classrooms, these Indigenous students are left to deal with conflicts between science and their worldviews on their own (Aikenhead, 2002).

We should be mindful of how we discuss other ways of knowing in the classroom and actively acknowledge the validity and usefulness of multiple perspectives (Smythe and Cady, 2009). For example, when Western science and IKS are discussed in binary terms, they are put in conflict with each other, and one is set up to be "superior" to the other (Tsuji and Ho, 2002; Fleer, 2008). The literature warns instructors not to convey that IKS require validation from Western science, but to clearly express that IKS are independent knowledge systems that do not need the approval of Western science to be true (Albuquerque *et al.*, 2021). Incorporating these suggestions can help instructors of Indigenous students use more culturally competent practices, just as we strive for cultural competence in other domains, such as with religious students (Barnes and Brownell, 2017; Lindsay *et al.*, 2019).

What might exploring other ways of knowing look like in a biology course? An instructor might simply start by verbally acknowledging that science is not the only way of knowing when teaching the nature of science, an act that takes very little instruction time yet shows respect for other worldviews. Larger steps may include having a short class discussion, entire class period(s), and/or homework assignment(s) about various ways of knowing. Instructors could ask students what ways they have learned about the world and use student ideas to teach that there are many ways we gain knowledge (e.g., language, reason, religion, IKS/TEK, physical senses, experience, memory, intuition, imagination, emotion). Through class discussions and/or assignments, students can compare and contrast these ways of knowing with the philosophy of science, consider the unique benefits and strengths of each type, and explore the situations and contexts in which different ways of knowing best apply. In any of these examples, instructors should explicitly avoid putting down other ways of knowing and aim to be enthusiastic when students bring up other ways of knowing outside science throughout the course.

Teach Holistically

In the literature, the most common suggestion to consider when including TEK in science education was to be holistic in teaching. Indigenous ways of knowing are generally holistic in nature, wherein the focus is placed on the reciprocal and interconnected relationships between people, nature, and the land (Snively and Corsiglia, 2001; McNally, 2004; Acton *et al.*, 2017). Additionally, emotional, spiritual, intellectual, social, and physical concepts can often be encompassed in a single idea (Smythe and Cady, 2009). Furthermore, the world is viewed as an interconnected whole in many Indigenous cultures, wherein humans are not regarded as more important than nature (Snively and Corsiglia, 2001; Smythe and Cady, 2009). This fits in well with evolutionary theory and humans' place in the Tree of Life, subject to the natural processes that affect all living things. The literature suggests that Indigenous students

TABLE 1. Suggestions for making biology classrooms more inclusive for Indigenous students

Suggestion		References
Explore other ways of knowing.	Actively acknowledge that there are other ways of knowing about the world, such as various IKS, that are not encompassed in the Western worldview.	Garrison, 1994; Tsuji and Ho, 2002; El-Hani and de Ferreira Bandeira, 2008; Mack *et al.*, 2012; Acton *et al.*, 2017; Howard and Kern, 2019a,b
	Use care when discussing examples of TEK in a Western science framework by emphasizing that TEK refers to different ways of knowing that are not meant to fit into or prove Western science, but exist on their own.	Shizha, 2007; Fleer, 2008
	Express the validity of other ways of knowing and avoid setting up Western science as the only "correct" way of understanding the world.	Garrison, 1994; Nelson-Barber and Estrin, 1995
Teach holistically.	Be holistic in teaching by focusing on making connections between topics and drawing from other sources of knowledge (e.g., emotions, spirituality, cultural values).	Haukoos and Satterfield, 1986; Nelson-Barber and Estrin, 1995; Davison and Miller, 1998; Snively and Corsiglia, 2001; Michie, 2002; McNally, 2004; De Beer and Whitlock, 2009; Kimmerer, 2012; Acton *et al.*, 2017; Zidny and Eilks, 2018; Howard and Kern, 2019b
Establish a classroom culture of respect.	Establish a classroom culture that incorporates more diverse values to allow Indigenous students to better identify with the material and values being taught.	Armstrong *et al.*, 2007
	Foster diversity in your classroom as an asset.	Lee, 2001; Rich, 2012
	Recognize and use Indigenous knowledge from students.	Tanner and Allen, 2007; Appanna, 2011; Kimmerer, 2012
	Foster and enforce a culture of respect in your classroom.	Tanner and Allen, 2007; Appanna, 2011; Kimmerer, 2012
	Acknowledge when content is considered sacred to other cultures.	Fonua, 2018
	Build awareness of cultural assumptions, stereotypes, and expectations in your classroom.	Ignas, 2004; Tanner and Allen, 2007
	When asking questions about students' cultures, be respectful and culturally appropriate in and outside the classroom.	Ignas, 2004; De Beer and Whitlock, 2009; Nam *et al.*, 2013; Fonua, 2018
Explicitly include TEK in biology courses.	Use examples of both TEK and Western science in teaching to enhance learning .	Barnhardt *et al.*, 1998; Haig-Brown, 1995; Schroder, 2006; Johnson *et al.*, 2014; Rioux *et al.*, 2018; Rioux and Smith, 2019
	Discuss and acknowledge differences between TEK and Western science but also highlight their compatibility.	Kimmerer, 2002; Le Grange, 2007; Kimmerer, 2012
	Use contemporary examples of TEK, such as the current contributions of Indigenous peoples to conservation, sustainability, and medicine.	De Beer and Whitlock, 2009; Schmidt and Stricker, 2010; Easton, 2011; Kim, 2015
	Research and highlight local TEK that may be more relevant to Indigenous students in your class.	De Beer and Whitlock, 2009
	Acknowledge that TEK is a Western construct, perhaps share quotes from papers that oppose or critique the idea of TEK.	Kim *et al.,* 2017
Include Indigenous experts.	Include Indigenous experts and leaders in TEK integration from the beginning.	McKinley *et al.*, 1992; Davison and Miller, 1998; Nadasdy, 1999; Johnson *et al.*, 2014; Kimmerer, 2013a
	Ask for permission to use Indigenous knowledge in classes and always provide credit to the original knowledge holders.	
	Collaborate with local leaders and Indigenous experts to build lessons that incorporate TEK.	
	Incorporate resources into your class that expose students to Indigenous voices, such as online videos, podcasts, articles, or books.	

(*Continued*)

TABLE 1. Continued

Suggestion		References
Incorporate Indigenous languages as more than "token words."	Use terms from the culture's language as much as possible, including Indigenous names of places, plants, and animals.	Dong, 2002; McKinley, 2005; Heaton *et al.*, 2011; Sutherland and Swayze, 2012a; Kimmerer 2013a
	Consult with Indigenous people on terminology and language that can be respectfully included in lessons, or invite language experts to come in and teach about the language.	
	Discuss the importance of language and how it shapes the way we think, perhaps by reading and discussing the chapter on language from *Braiding Sweetgrass*.	
Use common evidence-based practices.	Incorporate more hands-on activities.	Smith, 1982; Tanner and Allen, 2007
	Use storytelling and metaphors.	Snively and Corsiglia, 2001; Kimmerer, 2002; Moitra, 2014; Hadzigeorgiou, 2016
	Use evidence-based active-learning practices, such as sitting at the same level as the students, waiting longer for questions to be asked, placing emphasis on discussion instead of lecture, implementing small-group work, and using more visually oriented slides.	Haukoos and Satterfield, 1986; Freeman *et al.*, 2014; Theobald *et al.*, 2020

learn better with a holistic teaching approach than the reductionist approach that can be typical of Western science teaching (Nelson-Barber and Estrin, 1995; Michie, 2002; De Beer and Whitlock, 2009; Kimmerer, 2012; Howard and Kern, 2019b).

What might teaching holistically look like in the biology classroom? Instructors can intentionally teach the "whole person" by discussing students' emotional, spiritual, and social connections to the topics they are teaching. For example, after teaching about conservation biology, an instructor could ask students how this impacts their lives, how they feel emotionally about it, and/or how their cultural values align with or conflict with conservation values taught in class. Instructors can be mindful of the way we discuss abiotic factors, as many Indigenous cultures endue nonliving things with spirit (Kimmerer, 2013a). Intentionally being more holistic in our teaching is likely to benefit all students as they connect what they are learning to their values. In addition, by being exposed to the holistic nature of TEK, students who see humans as separate and different from nature may be more likely to see humans as important parts of ecosystems and integrate human impacts into their systems thinking. Holistic learning could also help students understand the societal and cultural context of their scientific knowledge and gain "a broader view of the world" (Zidny and Eilks, 2018).

Establish a Classroom Culture of Respect

Instructors must create a culture of respect in the classroom to effectively bring together Indigenous and Western ways of knowing (Lee, 2001; De Beer and Whitlock, 2009; Kimmerer, 2012; Rich, 2012; Nam *et al.*, 2013). When a classroom culture of respect is established, it aids Indigenous students as they cross borders between their culture and the culture of science (Appanna, 2011). When diversity is respected and viewed as an asset, we open the door for all students to learn in a culturally meaningful way (Lee, 2001). Instructors are the ones who build awareness of cultural assumptions, stereotypes, and expectations in their classroom (Ignas, 2004; Armstrong *et al.*, 2007; Tanner and Allen, 2007). If teachers do not understand or respect the cultures and backgrounds that their students come from, tension can arise (Chang and Rosiek, 2003). Even when teachers do understand the cultures and backgrounds of their students, there can still be conflict if

TABLE 2. What to avoid when integrating TEK in biology classrooms

Suggestion	References
Do not change or force Indigenous cultures to fit where you want it to fit in curriculum.	Kim *et al.*, 2017
Do not caricaturize aspects of the culture or use token examples out of context.	Michie, 2002; Fleer, 2008; Snively and Williams, 2008; Appanna, 2011; Heaton *et al.*, 2011; Kidman *et al.*, 2011; Sparkes and Piercey, 2015
Do not use token words (i.e., do not take Indigenous words out of context or simplify their meaning to fit into your lesson).	Heaton *et al.*, 2011
Do not exclude local cultural experts and leaders when integrating TEK in your classroom.	Nadasdy, 1999; Howard and Kern, 2019b
Do not be disrespectful of any cultures or students.	Ignas, 2004; De Beer and Whitlock, 2009; Nam *et al.*, 2013; Fonua, 2018

proper integration/understanding is not elicited in the classroom in a respectful way (Chang and Rosiek, 2003).

How can this culture of respect be established in the biology classroom? Instructors can be intentional about how they address/present other cultures in their classes (De Beer and Whitlock, 2009) and acknowledge when content they are teaching is considered sacred to other cultures (Fonua, 2018). For example, an anatomy instructor can be aware that many cultures view cadavers as sacred and explicitly talk about this with their students. Similarly, ecology and conservation biology instructors can explicitly acknowledge that many Indigenous cultures view their relationship with the land as sacred. This could also be done in a more student-centered way, with instructors showing interest by asking students how their cultures view the subject matter. If students do share their views, instructors should then show interest and respect in their responses. As instructors will likely not be aware of everything that could be considered sacred by students, they can start the course by acknowledging that some material taught throughout the semester might be considered sacred or reverent to some students.

Ultimately, instructors need to set an example of acceptable classroom culture and ensure students are abiding by this culture of respect. Simple practices like thanking students for comments or questions and being enthusiastic and supportive when students bring up other knowledge systems can set a respectful tone. Instructors can also allow for students with different perspectives to disagree while validating and welcoming opposing viewpoints. When asking questions about students' cultures, teachers and classmates must be respectful and culturally appropriate in and outside the classroom (Nam *et al.*, 2013; Fonua, 2018). This can turn learning into a more positive experience for students who are more alienated by Western teaching (Ignas, 2004; De Beer and Whitlock, 2009). Many instructors are likely already striving for cultures of respect in their classrooms and can use these strategies to expand their awareness to include Indigenous students specifically.

Explicitly Include TEK in Biology Courses

Much of the literature on TEK and Western science discusses how these two knowledge frameworks are complementary and that aspects of both Indigenous and Western knowledge can be used to build on each other to enhance science education (Haig-Brown, 1995; Barnhardt *et al.*, 1998; Schroder, 2006; Smythe and Cady, 2009; Johnson *et al.*, 2014; Rioux *et al.*, 2018; Rioux and Smith, 2019). While these knowledge frameworks are compatible, they are not the same (Kimmerer, 2002; Le Grange, 2007). Thus, it is important to discuss and acknowledge differences between the two frameworks while allowing collaboration and compatibility between them (Quigley, 2009; Kimmerer, 2012).

It is imperative that teachers do not force TEK to fit where they want it to fit in their curricula (Kim *et al.*, 2017). Some Native peoples have expressed frustrations that the use of TEK feels like people are trying to be politically correct and that the feeble attempts at integration come across as though there was never a real intention of doing it well (Nadasdy, 1999). Some of these attempts have been referred to as "slap-a-feather-on-it" curricula, wherein single aspects of Native cultures are added to a curriculum to make it appear integrated (Howard and Kern, 2019b). When including TEK in biology classes, instructors should not caricaturize aspects of the culture or select tokens to be used as examples out of a cultural context (Michie, 2002; Heaton *et al.*, 2011; Kidman *et al.*, 2011; Sparkes and Piercey, 2015). Indigenous knowledge cannot be essentialized; however, that is what is often done (Fleer, 2008), leading to an oversimplification of complex cultures and knowledge systems (Michie, 2002). In the field of ethnobotany, for example, Davison and Miller (1998) assert that simply identifying Indigenous plants is not enough. Rather, the significance of the plants to the culture should be discussed within a religious, medical, and linguistic framework (Davison and Miller, 1998). Some efforts to include Indigenous knowledge in Western science have unfortunately been tokenistic and caricatured the cultural knowledge (Snively and Williams, 2008; Appanna, 2011).

So how could TEK be included in biology classes while avoiding common pitfalls? One approach to thoughtfully integrating TEK into biology classrooms might be to include *values* from TEK and *approaches and methodologies* from Western science when discussing a real-world problem (Kimmerer, 2002; McNally, 2004; De Beer and Whitlock, 2009; McCarter and Gavin, 2011; Cocks *et al.*, 2012; Kuwahara, 2013; Fonua, 2018). As an example, Waiti and Hipkins (2002, p. 7) give this suggestion:

> Students could be undertaking an inquiry into a water pollution problem in their local area. From Western science they could learn about nutrient over-enrichment of water (eutrophication) and its effect on living things in the waterway. They would probably learn how to identify a variety of indicative species, and various ways of measuring aspects of water pollution. From the perspective of *Te Ao Māori* they could learn about *wairua*—the idea of water having a life force that should be treated with respect. They would merge this with their science understanding/methods of inquiry to make an action plan for lobbying for solving the pollution problem.

This approach can be effective, because it incorporates important parts of both TEK and scientific ecological knowledge in the same lesson, demonstrating to students how the two knowledge frameworks are unique but compatible. This type of TEK inclusion would be easier in a region with a larger Indigenous presence and more established connections with Indigenous leaders.

Second, TEK can provide ideas for interesting questions scientists can ask, and instructors can show students that TEK and Western science can address similar questions despite using different methods. In the reviewed literature, this idea was especially common when integrating TEK into science labs. For example, De Beer and Petersen (2017) created a laboratory investigation on the role of ethylene in seed germination that provided an example of how TEK and Western science can lead to the same conclusions. They first discussed with students the ancient Chinese practice of burning incense in closed fruit storage rooms. Later, they highlighted how burning incense releases ethylene gas, which in 1901 was also shown in the scientific community as being influential to plant growth (De Beer and Petersen, 2017). This approach could be replicated with other phenomena to demonstrate practical applications of TEK, allow students to experience TEK in practice, and teach that different knowledge frameworks can lead to the same conclusions.

The idea that TEK can help generate new testable hypotheses has also been postulated elsewhere as a benefit of including TEK in Western science research (Albuquerque *et al.*, 2021). However, instructors should be thoughtful about how the compatibility between the TEK and Western science is portrayed. TEK is not meant to "prove" Western science, nor vice versa (Molnar and Babai, 2021). Furthermore, instructors can discuss that different ways of knowing often lead to the same outcome but may sometimes draw conflicting conclusions.

Stories and oral narratives are another type of TEK discussed in the literature (Kimmerer, 2002; Armstrong *et al.*, 2007). Examples of TEK in oral narratives include information about shifts in land use, overfishing, and pollution and how these things correlate with changes in animal migration routes and changes in plant and animal populations (Snively and Corsiglia, 2001), which could be especially relevant in ecology or conservation units. Telling traditional stories has the potential to teach important ecological principles in a way that resonates with Indigenous students. This was done in a geology class that included videos of tribal elders relaying creation stories of places and discussions of the significance of local places to Indigenous peoples (Johnson *et al.*, 2014). These creation stories were specific to Indigenous peoples of the Northern Rocky Mountains in western Montana, and they closely parallel what is known about the formation of the region from geology (Johnson *et al.*, 2014). Learning these Indigenous creation stories increased Native American students' engagement with the material and their achievement on science assessments (Johnson *et al.*, 2014). It also inspired new questions for geology students to investigate regarding how certain geologic features were formed (Johnson *et al.*, 2014). Including TEK in this way would require collaboration with tribal leaders and cultural experts and may be easier in locations that have clear overlap between Indigenous creation stories and geologic history. However, if these are not available, instructors could find examples from other places, such as those in the resources developed by Johnson *et al.* (2014).

The literature emphasizes that instructors also include contemporary examples of TEK in their classrooms as opposed to strictly historical ones (De Beer and Whitlock, 2009; Schmidt and Stricker, 2010; Easton, 2011; Kim, 2015). Presenting TEK as if it is "preserved in a formaldehyde solution" discredits the value TEK brings to our modern world (De Beer and Whitlock, 2009), while using current examples communicates that Indigenous cultures are living and relevant today (Kim, 2015). Instructors could discuss the modern contributions of Indigenous peoples to conservation, sustainability, and medicine (Schmidt and Stricker, 2010; Sutherland and Swayze, 2012a). They could also have students consider Indigenous stakeholders when discussing contemporary conservation issues or case studies and use examples of how TEK is being used to address these issues (Easton, 2011). Additionally, teachers could provide diverse (including Indigenous) examples of role models in their biology classes (Tanner and Allen, 2007) to help students from diverse backgrounds see current examples of people like them in science. This could be done by inviting Indigenous speakers to a class discussion, showing videos of Indigenous knowledge holders explaining TEK relevant to class material (with permission), or even by going on a field trip to showcase local Indigenous knowledge. Many efforts are already in place to showcase Indigenous knowledge (e.g., outreach groups, nonprofit organizations, museums, education centers, restoration sites), so instructors can start by researching what is available in their community.

Finally, instructors could explicitly tell students that TEK is a Western construct that might cross into appropriation. Being open with students can invite productive conversations, so sharing quotes from Kim *et al.* (2017) that oppose TEK being included in biology classes could lead to a discussion with students highlighting that this is a complex issue. Instructors should be aware that some students might not like TEK or may be offended by its inclusion. Having an open discussion and acknowledging that not everyone views the inclusion of TEK in Western science favorably could help students who may feel uncomfortable with its inclusion feel seen and respected.

Data suggest that including TEK in the classroom has benefits for all students, not just Indigenous students. In a course devoted to Hawaiian TEK, researchers found that even students who came with predominantly Western mindsets learned from integrating Indigenous ways of thinking into their mental frameworks (Feinstein, 2004). These non-Indigenous students described gaining respect for Hawaiian culture (even stating that they no longer viewed it as primitive), experiencing increased environmental awareness, changing habits to take better care of the environment, having better appreciation for where things come from and how they are made, and gaining better understanding of the impacts of invasive species. Although this was a large-scale application of TEK inclusion, these benefits will likely extend to small efforts as well, but this should be validated by further research. By acknowledging diverse ways of knowing about the natural world in our classrooms, science education is improved for all students (Howard and Kern, 2019b).

Include Indigenous Experts

Before TEK is included in a biology classroom, Indigenous experts should be consulted and permission from the community should be granted to include TEK whenever possible (McKinley *et al.*, 1992; Davison and Miller, 1998; Nadasdy, 1999; Kimmerer, 2002, 2013a; Johnson *et al.*, 2014). A study found that when students consulted with local tribal elders to learn about traditional plants, 82% of students had increased motivation to learn and research medicinal plants, and there was an increase in student engagement, appreciation of IKS, and excitement toward applying Indigenous knowledge (Kellogg *et al.*, 2010). Approaches like this demonstrate how linking elders, youth, and other community members can result in a successful integration of TEK and Western science (Feinstein, 2005; Kellogg *et al.*, 2010).

Omitting Indigenous voices while integrating TEK can create tension in classrooms (McKinley *et al.*, 1992), cause TEK to lose its intended purpose if misinterpreted, and result in Indigenous ownership and intellectual property being lost (Smythe and Cady, 2009). In Indigenous ways of knowing, knowledge is often inseparable from responsibility for that knowledge (McNally, 2004; Kimmerer, 2012). Non-Indigenous people are not entitled to Indigenous knowledge, and any denial of knowledge should be respected (Kimmerer, 2002). TEK needs to be protected from exploitation; thus, permission must be sought and given when including TEK (Kimmerer, 2002). Credit should be given to individuals and communities who practice the

included TEK, and any Indigenous informants or contributors should be cited (Kimmerer, 2002). The integration of TEK in biology education must be done ethically; for further reading on principles of ethical TEK partnerships, see Robinson *et al.* (2021) article on the topic and Kimmerer's (2002) section on the protection and appropriate use of TEK.

How might instructors begin to include Indigenous experts? The first step might be to research Indigenous people who live nearby and the ancestral owners of our institutional lands. In addition, many institutions and communities have Indigenous outreach programs or clubs that may be willing to provide resources or connect instructors with Indigenous contacts. Instructors should explicitly ask for permission to include any information learned from Indigenous experts in the classroom and give proper attribution in the classroom.

Non-Indigenous instructors can also provide their students with valuable opportunities to hear Indigenous voices by using online or other available resources. Instructors can find articles or videos by Indigenous people and include them in class activities or homework assignments. Books written by Indigenous authors, such as *Braiding Sweetgrass* (Kimmerer, 2013a), could be woven into the curriculum throughout the course, or instructors could assign relevant passages and have students relate the material to what they are learning in class. Clear citations should also be included if instructors use publicly available articles, videos, and/or books from Indigenous sources in their classroom.

Incorporate Indigenous Languages

The literature also suggests that Native languages need to be included where possible when integrating TEK in classrooms (Lee, 2001; McKinley, 2005; Shizha, 2007; Heaton *et al.*, 2011; Sutherland and Swayze, 2012a,b). This is important, because language is inextricably tied to culture, and separating cultural values out of the language may have negative consequences (Dong, 2002; McKinley, 2005; Heaton *et al.*, 2011; Kimmerer, 2013a; Sutherland and Swayze, 2012a). When we attempt to reconstruct IKS in another language, we rewrite its meaning (Michie, 2002). Ideally, when discussing TEK, instructors should use terms and names from the culture's language as much as possible and be sure to acknowledge the importance of language in shaping how we think (Kimmerer, 2013a). A great resource for this is found in *Braiding Sweetgrass* (chap. 22), and instructors could even share this excerpt with students in class or as assigned reading. While including language is important, simply using a token word here or there is not the correct way to integrate Native cultures into science (Heaton *et al.*, 2011). Thus, instructors should consult with Indigenous experts on how and when to respectfully include Indigenous language in curricula (McKinley, 2005).

What might incorporating Indigenous languages into the biology classroom look like? Practically, it may be difficult for non-Indigenous instructors to effectively incorporate Indigenous languages in biology classrooms while avoiding the use of token words. For widespread implementation of this suggestion, more evidence-based direction and resources will be needed (McKinley *et al.*, 1992). Perhaps instructors unfamiliar with Indigenous languages can start with including the Indigenous names for places and organisms. This can be done when sharing examples of TEK, creating local food webs with Indigenous names, or giving both local and scientific names for a species or place in class examples. To avoid using Indigenous words as tokens, the way we introduce Indigenous words may be important. Perhaps we can acknowledge the complexity of language and convey that the full meaning behind a word is difficult to encapsulate, but we can express that one meaning of the word relates well to the topic in discussion. However, more direction from Indigenous people in the literature on practical ways to use the language without tokenizing it would be helpful. Again, consulting Indigenous experts about including Indigenous language is likely the best solution.

Use Common Evidence-Based Practices

In the literature, many suggestions for inclusive pedagogy for Indigenous students overlap with evidence-based practices suggested for all students. For example, Haukoos and Satterfield (1986) suggested that Native American students would benefit from instructors spending more time at the same level of the students, emphasizing discussion instead of lecture, pausing longer when inviting questions, and implementing small groups. In addition, Indigenous students have been found to benefit more from visual, oral, practical, hands-on, and experiential teaching than from analytical, verbal, written, passive, and theoretical teaching (Appanna, 2011; Sutherland and Swayze, 2012b). Thus, Indigenous students benefit when we incorporate more hands-on activities in the classroom (Smith, 1982; Tanner and Allen, 2007) and use storytelling and metaphors to teach (Snively and Corsiglia, 2001; Kimmerer, 2002; Armstrong *et al.*, 2007).

Practices such as class discussion, small-group work, and hands-on experiential learning are likely to benefit all, as evidence abounds that active-learning practices lead to larger learning gains than passive lecturing for all students (Freeman *et al.*, 2014). Active-learning practices have also been shown to close achievement gaps for other underserved groups, not just Indigenous students (Theobald *et al.*, 2020). Using narrative thinking and storytelling has also been suggested as a learning tool in science education for all students, not just those from an Indigenous background (Moitra, 2014; Hadzigeorgiou, 2016). In summary, instructors can intentionally modify instruction to meet diverse student needs, while always maintaining high expectations for all students (Tanner and Allen, 2007).

CONCLUSIONS

It Is Worth the Effort

Even though including TEK in biology classrooms is a daunting task, it has the potential to increase the representation of Indigenous students in science and create meaningful learning opportunities for all students (Easton, 2011; McCarter and Gavin, 2011; McKinley, 2020). For Indigenous students, the hypothesized benefits of including TEK are increased science identity, scientific literacy, content knowledge, belonging, achievement, and retention (McKinley, 2005; Patchen and Cox-Petersen, 2008; Kim, 2015; Brown, 2017; Rioux *et al.*, 2018). For non-Indigenous students, benefits could include the ability to better solve critical environmental issues (Berkes, 1993; Gadgil *et al.*, 1993; Kimmerer, 2013b), an increased understanding of the importance of considering Indigenous stakeholders in management decisions (Siebert and Belsky, 2007; Schmidt and Stricker, 2010;

McCarter and Gavin, 2011; Cocks *et al.*, 2012), an increased understanding of systems thinking (AAAS, 2011), and a demonstration that science is for everyone (Ruef *et al.*, 2020).

Implications and Future Research Directions

For instructors who want to start integrating TEK into their science classes now, we have discussed multiple methods that can be applied (Table 1) and avoided (Table 2). We acknowledge that instructors' context may impact their ability to include specific examples of TEK with input from Indigenous experts and use Indigenous languages appropriately. For example, implementation may be easier in regions where relationships with Indigenous people are more established, respected, or accessible; by instructors who are more familiar with Indigenous peoples and knowledge systems; or in student bodies who are more receptive and culturally diverse. Regardless, we can all begin by acknowledging diverse ways of knowing, teaching holistically, being respectful of different worldviews, and trying other ideas from Table 1.

Though the suggestions in this essay are a good place to start, further research and resources are needed on how to effectively integrate TEK into science curricula, including more input from Indigenous leaders, researchers, instructors, and students. Qualitative research investigating Indigenous students' experiences when TEK is incorporated in their biology course would be valuable and could provide direction for future integration. Both qualitative and quantitative research would be helpful to understand the impact of the instructor's cultural identity, the scale of the integration (small examples vs. thorough integration throughout courses or curricula), the match between students' specific cultures and the culture of the TEK included, and the effectiveness of general discussions of ways of knowing versus explicit examples. We also need to have a conversation as a community about if and how TEK examples should be shared. If they are shared, we would advocate for the inclusion of education on the cultural competence needed to use them in the classroom without tokenization and appropriation.

As we continue to strive for more inclusive classrooms by acknowledging Indigenous ways of knowing and using TEK examples, it will likely be a learning process and we may make mistakes. As the literature warns, we risk appropriation and tokenization of IKS when we try to fit them into a Western paradigm. However, we must humbly and carefully engage in this messiness and continue this important dialogue, else we will maintain a status quo of inequity, exclusion, and erasure (Acton *et al.*, 2017). There is no "one size fits all" instructional approach for integrating TEK in science classrooms (Quigley, 2009), but the suggestions in this essay are a good place to start. Our hope is that we, as non-Indigenous instructors, can humbly and incrementally help reverse Indigenous erasure while we make continual course corrections and learn from Indigenous students and experts.

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