Watching the Skies: An Overview of Indigenous Astronomy Curricula for Canadian K-12 Teachers

Michael O'Shea (✉ michael.oshea@mail.utoronto.ca)
  Ontario Institute for Studies in Education, University of Toronto   https://orcid.org/0000-0003-2267-0999
Pratishtha Kohli
  Ontario Institute for Studies in Education, University of Toronto
Hilding Neilson
  David A. Dunlap Department of Astronomy & Astrophysics, University of Toronto

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Abstract

There is a growing body of Indigenous astronomy curricula and resources from Turtle Island for Canadian K-12 science teachers. Canadian teachers, particularly non-Indigenous teachers, may be interested in teaching Indigenous astronomy and Indigenous perspectives, but may not be sure where to start or how to do so authentically. Using a framework that centers Indigenous Knowledges, we carried out a systematic survey of online curricular resources that identified 82 online Indigenous Astronomy Knowledges (IAK) and categorized them according to Indigenous tradition, media type, and language. We put this survey in context by emphasizing Indigenous astronomy and research as living and equivalent knowledge systems that can be taught on their own or alongside traditional Western astronomy. Centering this discussion around Indigenous research values, such as relationships, respect, and reciprocity, we emphasize the importance of embracing Indigenous curricula intentionally and thoughtfully to go beyond superficial "Indigenizing/Decolonizing" of the classroom. Authentic inclusion of Indigenous Knowledges could take a number of forms, including presenting Indigenous astronomical concepts and terms as valid and equal to Western knowledge, and helping students understand the interconnectedness of knowledge and the importance of relationships in science.

Background

Kovach (2009) discusses the importance of introducing the "researcher-in-relation," connecting the work that one does with a community's interests and needs, as well as understanding why individuals conduct the research that they do. The two lead authors of this study are Settlers who partially undertake this research in order to better understand their own relationship and potential allyship with Indigenous communities[1]. In this spirit of allyship and being-in-relationship, our study seeks to systematically identify online Indigenous Astronomy Knowledges (IAK) that Ontario K-12 teachers may use in the classroom. It also explores strategies for teachers to meaningfully and authentically integrate Western and Indigenous astronomy. Our study emerged from our coursework in Indigenous Worldviews, Studies, and research methods and through conversations with science teachers and with Indigenous faculty such as the paper's third author.

Astronomy is taught in Ontario in grades 6, 9, and 12, but our conversations with high school science teachers[2] reveal that there is little time to fit in all aspects of Western astronomy itself, and contributions from non-Western knowledges, including Indigenous Astronomy Knowledges[3] (IAK). As a result, while some teachers expressed interest in integrating Indigenous astronomy resources into their teaching, they feel that there is not enough time to synthesize Western topics of astronomy, let alone Indigenous ways of learning (personal communication, February 21, 2019). In addition, many teachers are afraid of interacting with Indigenous resources for fear of disrespect and appropriation or simply due to lack of understanding. Limited exposure to astronomy, Western or Indigenous in the K-12 system, has implications for students pursuing post-secondary studies in astronomy or astrophysics or science in general.

One of the issues with integrating Indigenous Knowledges with teaching astronomy in elementary and high schools is that this work is not integrated into traditional post-secondary education. How can teachers with non-Indigenous heritage be expected to be able to share and integrate Indigenous Knowledges when this integration of Knowledges is not included in their own leaning and training experiences? Most university programs that offer astronomy courses focus on topics in astronomy ranging from the Solar System to the Big Bang theory. This content is reflected in textbooks that encompass the perceived basics of astronomy and sample topics that have been traditionally considered important in Western academy (e.g., Bennett et al. 2019; Koupelis, 2014.). These textbooks typically follow similar prescriptions for presenting astronomy and typically only have a few pages in the introductory chapters discussing Indigenous Knowledges. That discussion usually mentions topics like the Big Horn Medicine Wheel, Aztec and Mayan Calendars, Hawaiian or Pacific Islander wayfinding. This brief overview is discussed through the lens of archeoastronomy and from Indigenous perspectives. Even within those discussions, there is usually integration of Eurocentric constellations or ancient European architectures that have solar and stellar alignments. The brief overview, and lack of depth given when considering Indigenous Knowledges, and their presentation before the 'real' astronomy places the Indigenous Knowledges as being of lesser value than the Eurocentric knowledges. It also suggests them to be outdated modes of anthropological study. There is little to no discussion about Indigenous Knowledges in modern contexts or of Indigenous sky knowledges as equally valid ways to view the Universe.

Therefore, over the course of this paper, in addition to identifying online IAK content, we seek to understand how teachers could introduce this content in a meaningful way that transmits Indigenous worldviews alongside Indigenous content. It is important to create new systems of learning where existing hegemony of Eurocentric knowledge can be challenged. We hope to do our part in creating more inclusive, in-depth understandings of astronomy for youth, incorporating greater concepts around the duties we have towards this land and the peoples who have called it home for thousands of years.

This paper reports on our research findings and suggests strategies for Ontario K-12 teachers seeking to integrate Indigenous Knowledges in their astronomy content. We preface our findings through a review of literature about Indigenous education and curriculum in the Settler state of Canada and its province, Ontario. We continue with a description of our methodology, before outlining our principal findings. A full breakdown of our systematic review of online IAK is provided in the Appendix. Following our findings, we provide recommendations for teachers before moving onto a reflection on our methodologies. We end with a conclusion and a description of future research directions.

This study also focuses on understanding how to share IAK material with respect, appreciation, and intentionality. When looking at Indigenous astronomy and introducing it into existing curricula, it is important to understand the place of Indigenous Knowledge in the classroom and in Canadian society. Studying Indigenous content without embracing Indigenous "ways of learning," such as by inserting portions of it into a pre-existing Western syllabus, does a disservice to the traditional knowledge being imparted and is tokenistic.

Footnotes:

[1] We are a team of two Settler researchers and science educators at a Canadian university working and one Indigenous astronomer. The land on which the university operates and where we are students is the traditional land of the Huron-Wendat, the Seneca, and most recently, the Mississaugas of the Credit River for thousands of years. Today, this meeting place is still the home to many Indigenous people from across Turtle Island.

[2] These teachers were enrolled in a master's level course for secondary school science teachers at a Canadian university.

[3] We capitalize Knowledge in this paper when used in reference to Indigenous Knowledge to emphasize Indigenous worldviews and wisdom as powerful and equal to European ones. For related reasons, we capitalize "Indigenous" to refer to the peoples, civilizations, and their knowledge systems at home on Turtle Island (North America). Indigenous peoples have lived on these lands for many thousands of years before European contact and colonization. Worldwide, "Indigenous" is a general term that refers to the 370 million people who have characters unique and "distinct from the dominant societies in which they live" (U.N. Permanent Forum on Indigenous Issues, 2019).

Review Of Literature

Indigenous Knowledge has been systematically uprooted and destroyed in the colonial history of Canada (Simpson, 2014). Through colonial scholarship, Eurocentric paradigms, and atrocities committed against Indigenous peoples such as the Residential schools, the Canadian state continues to discredit and forcibly remove understanding of this Knowledge from entire segments of society under the guise of assimilation (Simpson, 2011).

According to Battiste (2000), there has been a push to harmonize Indigenous and Eurocentric knowledge in order to restore dignity, apply fundamental human rights and heal Indigenous communities in the twenty-first century. Leroy Little Bear (Battiste & Barman, 1995) imagines a post-colonial society that allows for First Nations people to create their own sustaining and nourishing realities. Truly Indigenous education and curricula must:

….develop Aboriginal consciousness... [in order to] develop a greater appreciation of wholeness, connectedness, and relationships, the essence of the spiritual and the educational journey (Battiste & Barman, 1995, pg. xvi)

Education is one of the key elements in the struggle of regaining control over their lives as communities and nations for First Nations people. This can only be achieved through the transformation of education from a space of assimilation to one of self-expression. and self-determination is therefore, in order for

there to be a push in the integration of Indigenous and Eurocentric paradigms of learning, it is important to take a holistic approach (Castellano, in Dei, 2002).

There have been steps towards accomplishing this in parts of the Canadian province of Saskatchewan since 2006, where some schools have integrated Indigenous ways of knowing into existing science curricula, citing the benefits of a holistic curriculum that moves students away from focusing on often unrelatable scientific terminology and jargon. The curriculum emphasizes more integrative modes of thinking, and making knowledge more accessible, particularly to students who do not come from traditionally Eurocentric spaces of learning (Aikenhead & Elliott, 2010). Additionally, the Truth and Reconciliation Commission (TRC) of Canada called for greater education of accurate histories of Indigenous communities in Canada and Indigenous methodologies of knowing in K-12 curricula (TRC, 2015). The Indigenization of current astronomy curricula is a step toward this TRC Call for Action, and allows for students, at various levels of understanding, to embrace ideas surrounding Truth and Reconciliation into their own lives. It also allows for a deeper understanding that knowledge is not meant to be held by any particular individual or community, and that Eurocentric modes of thinking about astronomy are not the only valid resources that exist. Educators can go beyond simply inserting Indigenous astronomy curricula into existing learning and create a new curriculum that incorporates both modes of learning.

In Ontario, students receive instruction in astronomy in grades 6, 9 and 12 (Ontario Ministry of Education, 2019). However, teachers reported that they lack adequate time to delve into in-depth astronomy, making it all the more difficult to incorporate Indigenous Knowledge regarding the subject, despite an interest in incorporating such content into the curriculum (Ruddell, Danaia & McKinnon, 2016). This itself is a symptom of systemic issues that exist within school boards, as allocating time and resources to certain subjects over others are forms of Eurocentrism thereby prioritizing Western knowledge over Indigenous Knowledge of the same subjects. (Funding given to schools in Indigenous reserves is also significantly lower than that for schools off reserve; Fontaine & Sniderman, 2019). Quality and heterogeneity of education affects student achievement, suggesting that the integration of a more diverse, Indigenous curricula is important to the holistic development of students (Carr-Stewart, 2011). Aikenhead (2006) suggests that teaching scientific knowledge specifically through a Eurocentric lens leads to more students studying science merely to pass courses, rather than engaging in meaningful learning. This is particularly true for non-English speaking students who migrate to Canada or Indigenous students, who grow up in environments where there is different cultural learning about the sciences (Aikenhead, 2010). From a practical perspective therefore, under the current system, it is important to incorporate both Indigenous and Western methodologies, allowing for a wider worldview, in astronomy, physics, and other science courses.

Integrating Western and Indigenous Knowledges together is an idea that comes from the Mi'kmaw guiding principle of Two Eyed Seeing. In the words of Elder Albert Marshall, Two-Eyed Seeing is:

[T]o see from one eye with the strengths of Indigenous ways of knowing, and to see from the other eye with the strengths of Western ways of knowing, and to use both of these eyes together (Bartlett, Marshall, & Marshall, 2012).

According to Marshall, Two-Eyed Seeing allows for students to learn the science of astronomy through Indigenous practices of knowing, while incorporating both Western and Indigenous Astronomy Knowledge to form a more "wholeistic" understanding of what astronomy is and can encompass (Absolon, 2011). Marshall states that by fostering an active engagement with both ways of seeing, it allows for students to receive the support to slowly work towards decolonizing the classroom (Bartlett et al., 2012).

In 2019, First Nations, Métis, and Inuit Studies was introduced into the Ontario Curriculum (First Nations, Metis and Inuit Revised Curriculum, 2019). This course focuses upon the experiences and histories of certain First Nations communities in Canada, with an aim to bring critical literacy to students, bridging gaps left by history curriculum and older, Native Studies curriculum. While this course is essential in providing a step forward from previous learning, it is important to include Indigenous Knowledges from across all curriculum, rather than only having specific courses that teach students this knowledge. This is because Indigenous Knowledge, as referenced in the new Ontario curriculum, emphasizes the importance of understanding community (relationships with one another), land (relationships with nature) and interconnectedness of all things (relationships with all creations through life balance. Therefore, teachers who incorporate Indigenous methods of learning into the current astronomy curriculum can emphasize the interconnectedness of students, stories and teachings in Indigenous astronomy, and European constructions of the night sky. Such an approach allows students to gain a better understanding of the land upon which they are learning, something that is essential as it is all of our duties to care for this land (Wilson, 2008; Absolon, 2011; Kovach, 2009).

Framework

Building on this review of literature, our framework aims to center Indigenous Knowledges (Absolon, 2011; Simpson, 2011), to celebrate such knowledge as a valid and rich tradition, and to question the primacy of colonial teaching methods in the academy.

Knowledge and knowledge-creation are connected to power. In *Pedagogy of the Oppressed,* Freire (2000) tells us those with power decide what is knowledge and the appropriate ways to create it. On Turtle Island, the dominant, colonizing West has discredited and attempted to fully erase Indigenous research — Indigenous ways to transform experiences into knowledge (Bechtel, 2016; Simpson, 2011). Eurocentric researchers are often critical of Indigenous methods, while Eurocentric values and research methods are the unspoken norm in schooling (Hudson & Ahlquist, 2003). Bechtel (2016) notes, "But what is often forgotten...by Eurocentric speakers is that the language they speak is rooted in power and dominance" (Bechtel, 2016, p. 449). Western and Indigenous ways of knowing are both empirical, both drawn from observable phenomena, but the Western knowledge system has become dominant through the processes of colonization, erasure, and genocide.

"Colonialism is not satisfied merely with holding a people in its grip and emptying the native's brain of all form and content...it turns to the past of the people, and distorts, disfigures and destroys it" (Fanon, 1963, p. 210). Education and curriculum become a means of conveying values and beliefs that serve the interests of the colonizers. History classes and textbooks, for example, in North America told the story of European contact and genocide from the Settler perspective, emphasizing Settler conquests and victories as positive and inevitable (Zinn, 2014). However, all courses, including astronomy in a Settler state like Canada may be imbued with Eurocentric or colonial values.

Whether observing the passing of seasons, monitoring caribou populations, or noting the phases of the Moon, all humans turn experiences into knowledge via the process of perception, analysis, and reflection (Bechtel, 2016). Western science, carried along by waves of colonization and the simultaneous destruction of Indigenous civilizations, has become synonymous with "science" as understood in the West and as taught in our schools. The hegemony of Western science has erased and discredited Indigenous Knowledge systems and research methods. Indigenous scholars, for example, remind us that research techniques and ways of knowing that may appear non-scientific to Eurocentric researchers are still valid, accurate, and culturally grounded ways of carrying out science. Embracing them inside the academy may mean Indigenous healing, revitalization, and resurgence (Simpson, 2011).

In order to use Indigenous Knowledge systems that challenge the content and effects of Eurocentric curricula, we identified resources that would serve an anti-colonial astronomy curriculum. Indigenous scholars have revitalized and developed a variety of Indigenous methods and codified Indigenous research values (Wilson, 2008). Smith (2012), for example, presents an Indigenous research model based on Pacific Ocean tides. The model's four directions represent four processes: decolonization, healing, transformation and mobilization (Smith, p. 116). The model's tides represent concepts essential to Indigenous resurgence (Simpson, 2016) and sovereignty: survival, recovery, development, self-determination (Smith, p. 116). Other Indigenous research methods include portraiture (Keene, 2018), Indigenous storywork (Archibald, 2008), weaving (Tachine, 2018), and "walking in beauty" (Davidson, 2018).

Smith's 25 Indigenous research projects (Smith, 2012) are also a useful way to frame our research. Our project fits into at least three of her projects that advance the case of Indigenous peoples: claiming, Indigenous storywork, and revitalization. Our project is designed to support the claiming of an Indigenous space in astronomy. Through the project, our aim is to elevate the work of Indigenous Knowledge keepers, such as those of astronomer Opaskwayak Cree Elder and astronomer Wilfred Buck (Buck, 2018). Finally, we hope that our project and the database it results in can serve as a springboard for other forms of revitalization.

Our methods and values are based on the recognition and celebration of Indigenous Knowledges as a knowledge system in their own right and as an equal alternative to Eurocentric ways of knowing (Bechtel, 2016). Unsurprisingly, there is "resistance within the academy to embracing Indigenous research methodologies" (Moreton-Robinson, 2016, p. 74). Eurocentric academics may "critique...Indigenous

research methodologies on the grounds that they are considered to be metaphysical and... lacking rationality" (p. 74). However, Western methodologies also "have metaphysical origins in Greek mythology and Judeo-Christian beliefs" (p. 74). Simpson (2011) goes further: "...we've all been bathed in a vat of cognitive imperialism, perpetuating the idea that Indigenous Peoples were not, and are not, thinking peoples" (p. 32). Western and Indigenous ways of knowing are both empirical, both drawn from observable phenomena. In addition to being empirical, Indigenous research methods are personal, deliberate, and relational.

Methods

The two Settler authors of the research team saw preparation to thoughtfully undertake this research as part of our method. We wanted to enter this research as prepared as we could be and with a "good heart" (Weber-Pillwax, 1999), while knowing the process of personal and institutional decolonization is an ongoing project. Toward this end, we enrolled in several Indigenous research courses, attended workshops, such Traditional Medicine Workshops, and built relationships with Indigenous faculty and peers. Through these experiences we gained a deeper appreciation for Indigenous Knowledges and became aware of how the academy and Eurocentric research methods further the colonial project. Our peers and teachers helped us understand our blind spots and challenged us to think deeply about how our work could further the common work of decolonization and centering Indigenous Knowledge.

We employed a systematic survey of online curricular resources as our entry point in the topic and way to address our research question, "What kinds of IAK resources for K-12 teachers in Ontario exist online?" As a form of research, such systematic reviews bring "together what is known from the research literature using explicit and accountable methods" (Gough, Thomas, & Olive, 2012, p. 1). Our methods also have much in common

The table generated by our systematic review also serves as a resource list of online Indigenous content for Settler K-12 science teachers. We were inspired by such repositories of Indigenous Knowledge online such as the Deepening Knowledge project at the University of Toronto and scholars who have examined IK online. These include Wemigwans (2018) who proposed understanding online Indigenous knowledge as "digital bundles."

We chose online formats for our review because we wanted content to be easily accessible to science teachers across Ontario, though we were aware of some of the drawbacks of online resources, such as limited representation and problems in authorship, and unequal access to high-speed Internet connections. Much of Indigenous Knowledge is not readily available online as the transition to electronic record keeping is still evolving amongst communities (Wemigwans, 2019) nor may be considered an appropriate avenue from some Indigenous Knowledges. Thus, our project aims to accomplish several things: 1) examine Ontario science curricula for its level of inclusion of Indigenous content 2) center Indigenous Knowledge, and 3) create a useful resource for science teachers. Settler teachers could

meaningfully and thoughtfully integrate IAK into the classroom. Thus, we added a fourth goal: 4) identify strategies for teachers to appropriately teach Indigenous content in the classroom.

We are not aware of any similar reviews of Indigenous science curricula, but we take our cue from other education and non-education studies that have conducted extensive literature reviews or reviews of curriculum and education programs. These include an analysis of university science curricula (Brabrand & Dahl, 2009) and Lebanese science curricula (BouJaoude, 2002), and a review of online learning studies (Means et al, 2009).

Informed by these studies and grounded in an Indigenous Knowledge framework (Absolon, 2011), our method was a systematic survey of online Indigenous astronomy education materials readily available to teachers, using Google, YouTube, and the databases of a large research university. We searched, in English, between February 11 and August 16, 2019.

Our search was intended to be exploratory, not exhaustive. We began our search looking for IAK from the Indigenous peoples whose traditional lands are occupied by the authors' university in Toronto. The university occupies the homelands of the Huron-Wendat, the Seneca, and Mississaugas of the Credit River (University of Toronto, 2020). Occupying the homelands of several Indigenous groups, Toronto is also home to Métis, Inuit, and urban Indigenous populations from across Turtle Island. The city is located in a Canadian province, Ontario, which is the territory of the Dene and Cree people (Native Land Digital, 2019).

We took this approach because of the importance of land to Indigenous Knowledges, the authors' location in Toronto, and the importance of avoiding a generalized "pan-Indigenous" or "pan-Native" approach. Simpson, noting, the importance of land-based education, writes, "Indigenous education is not Indigenous or education from within our intellectual traditions unless it comes through the land" (2014, p. 9). Indigenous peoples are connected to the particular land of their territories, and thus so if their knowledge.

While many Indigenous Knowledges may share certain elements or beliefs, there is enormous diversity in the Indigenous civilizations of North America. "Pan-native" is a term that groups distinct Indigenous identities, traditions, and knowledge together. While there may be symbolic or political advantages for disparate Indigenous groups to use a common term, such as "American Indian" in advocating for legal changes (Stonechild, 2006), pan-Native approaches "group everyone into one big category. (Monchalin, 2016, p. 3). The "all-encompassing term also defines and positions Indigenous identity according to a European colonizing perspective, a former of identity control that angers many." (Monchalin, 2016, p. 3). Grouping all Indigenous traditional together erases individual Indigenous Knowledges, can promote stereotypes (King, 2014).

We began our online search on Google, YouTube and the databases of a large research university using Boolean search terms based on our understanding of 1) Indigenous homelands on which the city of Toronto and the province of Ontario are located, 2) how astronomy content might be organized in a

search database. We searched for IAK of the Haudenosaunee Confederacy (to which the Seneca Nation belongs), the Anishinaabe Nation (to which the Mississaugas of the Credit River belongs), and the Cree. We also included "Ontario" as a search term to see if other IAK from the province known as Ontario might be generated, as well. In a future research direction, we should also search for "Ojibwe," often used synonymously with "Anishinaabe." (Mississauga of the Credit First Nation, 2020). Lee et al., (2014) for example, title their volume, *Ojibwe Sky Star Map - Constellation Guidebook: An Introduction to Ojibwe Star Knowledge.*

- "Astronomy" AND "Haudenosaunee"
- "Indigenous Knowledge" AND "Haudenosaunee"
- "cosmology" AND "Haudenosaunee"
- "Astronomy" AND "Iroquois"
- "Indigenous Knowledge" AND "Iroquois"
- "cosmology" AND "Iroquois"
- "Astronomy" AND "Anishinaabe"
- "Indigenous Knowledge" AND "Anishinaabe"
- "cosmology" AND "Anishinaabe"
- "Astronomy" AND "Ontario"
- "Indigenous Knowledge" AND "Ontario"
- "cosmology" AND "Ontario"
- "Astronomy" AND "Cree"
- "Indigenous Knowledge" AND "Cree"
- "cosmology" AND "Cree"
- "Astronomy" AND "Ontario"
- "Indigenous Knowledge" AND "Ontario"
- "cosmology" AND "Ontario"

After investigating each online source, we initially categorized according to the following metrics and categories:

- Creator/Author
- Title
- Published
- Year
- Type
- Indigenous Author/Illustrator/Partner

- Nation/Tradition of Indigenous Astronomy

After initially analysis, we added the additional categories

- Uses Indigenous vocabulary (At least one Indigenous word)
- French language source[4]
- Self-identified Indigenous Author/Illustrator/Partner (Identity apparent within resource without further research)

Footnotes:

[4] Roughly 10 million Canadians speak French, approximately 30% of the population (Statistics Canada, 2018). French is official language of Québec, and there are French language school boards throughout the country, as well as additional French immersion programs (FNCSF, 2020).

Results

In total, we located 82 online sources. One-half (41) were prepared by self-Identified Indigenous authors, illustrators, or partners; i.e., their identity was evident in reading the source alone without further research on our part (Table 4 in Appendix). When we carried out further research into the identity of sources' authors, illustrators or partners, this number of Indigenous authors rose to 50 sources, or roughly 60% (Table 3). An example of this is when an author may not self-identify as Indigenous in the introduction to a journal article but may self-identify on their faculty website. The top three media represented were "book," "article," and "multimedia" (Table 1). Several were complete lesson plans and others were YouTube videos or children's books. The top two Indigenous traditions represented were Anishinaabe and Haudenosaunee and reflect only our methodology. While we searched for online IAK resources of the traditional peoples of the territories now known as Ontario, our research highlighted other Indigenous groups, such as Navajo, Blackfoot/feet[5], and Inuit. We included these in our findings as well in Table 2. We also identified "pan-Indigenous resources," that did not refer in particular to the knowledge of specific peoples. A slight majority employed Indigenous vocabulary alongside Indigenous Knowledge (Table 5). Less than 5% however were Francophone resources, a finding that reflects our English-only search methods (Table 6).

Below is a summary of our online survey, with the individual count in parenthesis:

- We identified 82 sources.
- The top three media types are book (28); multimedia, including illustrations or video (22); news, magazine, or scholarly article (15); and astronomy guide (6). These categories were not exclusive or

exhaustive, and sources could be part of multiple categories.

- The top four Indigenous nations represented are Anishinaabe (25), Haudenosaunee (16), Cree (6), and Blackfeet (6).
- "Pan-native sources, or sources that grouped IAK together under such titles as "Stars of the First People: Native American Star Myths and Constellations," (Miller, 1997) accounted for 11 of the 82 sources.
- 60% sources were by an Indigenous author/partner/illustrator, either self-Identified in the resource or identified on another platform, such as a faculty website.
- The sources were recently published. The average published year was 2006, while the most common reported year was 2011.

Footnotes:

[5] Blackfoot Nation is the English translation of Siksikaitsitapi, whose homelands span southern Alberta and Saskatchean and northern Montana. Blackfeet is more commonly used south of the U.S.-Canada border (Blackfeet Nation, 2019; Dempsey, 2019).

Discussion

Our survey revealed some important facts about the state of IAK online. IAK does exist online and exists in a variety of formats. When school curricula are revised at the school, school board, or province-wide level there are rich online resources that teachers may include as they craft lesson plans.

However, we also recognize that elements of IAK do not exist online and may never. There are protocols that govern the sharing of Indigenous Knowledge. For example, some stories may only be shared at certain times of year or in certain places or heard by particular audiences (First Nations Studies Program, 2009; Lee et al. 2014). certain seasons or told by certain people. These protocols extend to the Internet: knowledge-keepers must give consent for knowledge to be shared online. Protocols must be followed to ensure Indigenous materials are treated respectfully and appropriately. Teachers who use IAK materials should seek our Indigenous teachers, elders, community members for guidance (Lee et al., 2014, pp. 36-37.

While some sources refer to IAK as "knowledge," others use terms like "myth" and "legend" that may minimize its importance. This is because the Western academy has historically dismissed Indigenous forms of knowledge such as storytelling because they are not "reliable" or "objective." One author described the challenge of introducing IK into the academy:

It has not been easy bringing Indigenous Knowledges into a scientist-practitioner training model...many scholars...view Indigenous Knowledges as non-scientific and primitive, confining them to "conceptual

reservations (Fellner, 2018, p. 35)

These include such titles as "Stars of the First People: Native American Star Myths and Constellations (Miller, 1997). Frequently the authors of such volumes are not Indigenous, and the use of such terms may be a way to delegitimize Indigenous science. However, this is not always the case. For example, *American Indian Myths and Legends*' is written by Indigenous authors Erdoes and Ortiz (1984).

The majority of sources present knowledge from Indigenous civilizations of Ontario, a finding that reflects our research methods and search terms. We were looking for sources that represented the particular IAK of the civilizations of what is now Ontario: knowledge is local and land-based. Tewa scholar and educator Gregory Cajete (1994) describes a "sacred view of Nature" and acknowledgement of interconnectedness of all things as characteristic of Indigenous education (p. 29). We wanted to avoid pan-Indigenous or pan-Native sources that have such titles as "Native American Astronomy" (Giese, 1997), which lump all Indigenous peoples and their Knowledges together. Our ability to locate Ontario-specific IAK is also encouraging as we expand our search to other territories on Turtle Island.

A majority (60.5%) of sources were created by Indigenous authors or co-authors, which is a good sign, but leaves room for improvement. Context, accountability, relationality is key to an Indigenous research paradigm (Wilson, 2008, p. 126), so if a Settler researcher does not have Indigenous life experience, they cannot bring the necessary context to an Indigenous research methodology. "Relationality" means that "ideas develop through relations we have with others, including kin, and that in our research we are accountable to those with whom we have relationships" (Dei, 2013, p. 29)

Kovach (2009) notes that Settler researchers "may not have the background to appreciate validity from an Indigenous perspective, where truth is found in the subjective, and validity is in the nature of the relationship with culture" (p. 149). Many Settler authors frame OAK as history, mythology, or stories, rather than contemporary knowledge.

To answer the second question, "How to use these resources thoughtfully and respectfully in the classroom." Teachers should incorporate the strategies and concepts that provide the all-important context for IAK facts and vocabulary. When school curricula are revised at the school, school board, or province-wide level there are rich online resources to include. We have listed some recommendations below on how to thoughtfully introduce Indigenous content into the classroom when teaching IAK (Bartlett et al., 2012; Institute for Integrative Science, 2019; Lee et al., 2014; Wilson, 2008):

- Intentional Learning of Indigenous Worldviews;
- Land-Based Learning;
- Recognizing the value of personal knowledge;
- Respecting Indigenous ways of knowing and OAK;
- Following proper protocols in use of OAK material;
- Seeking out Elders and native community members as partners and providing appropriate citations.

These strategies are reminders that curriculum designers can shape curriculum that values different modes of learning rather than creating competing curricula. This might be carried out in the spirit of two-eyed seeing and ethical collaborations between Western and Indigenous Knowledge systems (Venkatesan et al., 2019).

Future Directions

Our research is an initial exploration of online IAK, and, as such, we chose a relatively simple methodology. As such we are aware of some methodologies, including:

- our sampling technique,
- our use of particular search engines,
- our language and spelling choices, and
- our biases in categorization.

We reviewed 82 online sources out of the thousands that exist. We only included online sources. This leaves out IAK that is not and may never be online, because having that knowledge online might violate protocols. There are risks, but also promises, of representing Indigenous Knowledges online (Wemigwans, 2016). Finally, there remain many sources not explored, including resources outside Ontario. While our survey may result in a convenient database for teachers to access, our survey does not include strategies for integrating Indigenous content into the classroom in a thoughtful deliberate way.

Google, which also owns YouTube, is a private company headquartered in the United States not bound by Indigenous protocols and has its own interests and biases. Google searches and retrieves content by applying a search algorithm to content on the Internet it indexes; there is no evidence that Indigenous values are part of its algorithm or indexing (Google, 2020). As such, Google's search parameters may serve to privilege certain forms of knowledge and reinforce Western forms of knowledge production and learning. For example, context and relationships are important axioms of many Indigenous Knowledges. During a Google Search, Google searches through its record of websites it has indexed. During indexing, "Google analyzes the content of the page, catalogs images and video files embedded on the page" (Google, 2020). Indigenous Knowledges even when represented holistically online may be stripped down and decontextualized during the process of indexing. Biases will also creep in during the next step of the Search, "ranking," when the search engine decides what results are most relevant.

There are similar limitations to using a university library online database. An online database that searches an academic library may yield credible sources, scholar materials, and a wider range of media, including those behind Internet paywalls. However, academic libraries are guided by the same Eurocentric university values that are hostile to Indigenous people and may omit Indigenous ways of knowing.

Knowledge is organized in many academic libraries according to the Library of Congress system, which in addition to using English language, is based around Eurocentric conceptions of Knowledge. (There is a movement to create Indigenous-centered library organizational systems, such as the X̱wi7x̱wa Library at the University of British Columbia; X̱wi7x̱wa Library, 2020).

In the future we would like to move beyond Indigenous Googling and challenge some of our initial biases. We recognize the inherent drawbacks to our approach of "Indigenous Googling," that describes one-dimensional, superficial explorations of Indigenous Knowledges. While the term "Indigenous Googling" does not appear in the literature, "Googling Indigenous" does — in the work by Thom, Colombi, & Degai, 2016), who use the term to describe the use of Google Earth by members of the Indigenous Itelmen community of Russia's Kamchatka peninsula. Using Google and in collaboration with Western academics, the community sought "ways to preserve their critically endangered language and related cultural information" (p. 1).

Another area to improve upon in future research is our use of certain phrases, and our choice of language and spelling. For example, we searched in English, which excluded sources written in French (Canada's other official language) and sources written in any of the hundreds of Indigenous languages. We also used an Anglicized spelling or terms for certain Indigenous civilizations, which may have excluded other search results. For example, we used the search term "Anishinaabe," rather than "Ojibwe," "Anishinabek" (Anishinaabe people), or"Anishinaabemowin" (the Anishinaabe language). We searched for "Cree," rather than "Nēhiyaw." We did also did not search Indigenous writing systems, such as syllabics (Knife & Jay, 2019). By introducing "Ontario" into our search terms, we used a political definition and boundary set by the Canadian state, not Indigenous nations.

Further research will build upon our method of categorization. While categorization may have useful explanatory power and convenience for teachers searching for resources, there is researcher bias in the process of categorization. Just as Google categorization risks misrepresentation, so does researcher categorization. Such risks are heightened when the researcher is a Settler, who may lack the context and personal or community knowledge to understand and appreciate the IAK.

Finally, though we believe we reached "saturation" in our data given our parameters, there are many more sources to review. Saturation as defined by Hennink and Kaiser (2019) is used "determine whether it is adequate data from a study to develop a robust and valid understanding." After reviewing the first three pages of results on Google and the databases of a large research university, we reached saturation.

Looking to the future we should keep these limitations in mind as we plan our next steps, which may include the following more sources and more sources from Indigenous civilizations outside of Toronto, Francophone sources, and development of categories in closer consultation with Indigenous scholars or leaders. This work could be beneficial for: The Deepening Knowledge Project at the University of Toronto, an Indigenous Knowledge portal online, and Discovering the Universe, a Quebec-based program that supports science teachers in elementary and high school who teach astronomy (Deepening Knowledge Project, 2019; Discover the Universe, 2020).

Conclusion

Using an Indigenous Knowledges (IK) approach, we carried out a systematic survey of Indigenous Astronomy Knowledges (IAK) online resources. We identified 82 sources through Google searches, YouTube, and the databases of a large research university. We categorized these sources according to such metrics as media type, Indigenous civilization, and the language used.

In doing so we met the four goals of our paper as explored our research question:

1. Examine Ontario science curricula for its level of inclusion of Indigenous content,
2. Elevate Indigenous Knowledge,
3. Create a useful resource for science teachers, and
4. Identify strategies for teachers to appropriately teach Indigenous content in the classroom.

Encouragingly, our survey revealed that there are many resources available online, and importantly, resources that are from Indigenous civilizations of modern-day Ontario, which is important for a locally rooted, land-based curriculum (Wildcat et al., 2014). There is room to improve our research in the future and our tools of analysis. The majority of sources were created by Indigenous authors.

In carrying our review of literature, we also identified strategies to Indigenize the classroom. Authentic inclusion of Indigenous Knowledges could include using Indigenous language appropriately in teaching astronomy, recognizing the interconnectedness of knowledge, relationships and communities as well as the essence of the spiritual and the educational journey in developing a deeper understanding of the world around us.

Collections of information, such as the one we put together here, are limited and reflect only a portion of knowledge that exists on the Internet, rather than being an exhaustive list of the potential knowledge held and kept safe by Elders within First Nation, Inuit and Métis communities. That being said, through the curation and sharing of this knowledge, we hope to influence the astronomy curricula that currently exists, loosening the Eurocentric hold on education and knowledge in Canada.

Declarations

Conflict of interest

The authors declare that they have no conflict of interest.

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Appendix

Counts and percentages may equal more than the total sample size (n=82) because more than one category may apply to a given item; e.g. "media" and "article."

Table 1. Count of Resource Type

Type	Count
Book	28
Article	15
Multimedia	13
Video	6
Guide	6
Website	5
Blog Posts	4
Lesson Plan	4
Resource List	4
PowerPoint	3
Lesson Plan	3
Journal	3
Poetry	1
Planetarium Show	1

Table 2. Count of Resource by Tradition or Nation

Some items are counted twice if they can describe with more than one name; e.g. an Ojibwe resource will be counted as both "Ojibwe" and "Anishinaabe" or a Mohawk resource will be counted as "Mohawk" and "Haudenosaunee."

Tradition	Count
Count of Anishinaabe	25
Count of Haudenosaunee	16
Count of Pan-Native	11
Count of Lakota	9
Count of Blackfeet	6
Count of Cree	6
Count of Navajo	5
Count of Inuit	5
Count of Mi'kmaq	3
Count of Mohawk	2
Count of Dëne	2
Count of Dakota	2
Count of Ojibwe	2

Table 3. Indigenous Authorship

The count and percentage of resources that had Indigenous authorship (defined as an Indigenous author, illustrator or partner) are listed below. Indigenous authorship may not have been immediately apparent in the resource, but could be determined through further reading, such as visiting the website of the author.

	Indigenous Author/Illustrator/Partner?	
	Count	%
Yes	50	60.98
No	16	19.51
N/A	16	19.51

Table 4. Self-Identified Indigenous Authorship

The count and percentage of resources that had self-identified Indigenous authorship (self-identified Indigenous author, illustrator or partner) are listed below. Self-identified Indigenous authorship was immediately apparent by reading the resource (not through further research), such as by the author identifying their nation.

	Self-Identified Indigenous Author/Illustrator/Partner?	
	Count	%
Yes	41	50
No	28	34.15
N/A	13	15.85

Table 5. Indigenous Vocabulary

The count and percentage of resources that used Indigenous vocabulary (defined as at least one Indigenous word) are listed below:

	Uses Indigenous Vocabulary?	
	Count	%
Yes	44	53.656
No	14	17.07
N/A	24	29.27

Table 6. Francophone Resources

The count and percentage of resources that were written entirely or primarily in French are summarized below:

	Francophone Resource?	
	Count	%
Yes	4	4.88
No	78	95.12
N/A	0	0