Ten calls to action to integrate Indigenous Knowledges and perspectives into the Biosystems Engineering program at the University of Manitoba

Alyssa Ruta[1], Jillian Seniuk Cicek[2,*], Afua Mante[3], Marie Speare[4], and Randy Herrmann[5]

[1]*Department of Biosystems Engineering, University of Manitoba, Winnipeg, Manitoba Canada*
[2]*Centre for Professional Practice and Engineering Education, University of Manitoba, Winnipeg, Manitoba, Canada*
[3]*Department of Soil Science, University of Manitoba, Winnipeg, Canada*
[4]*Sciences and Technology Library, University of Manitoba, Winnipeg, Manitoba, Canada*
[5]*Engineering Access Program (ENGAP), University of Manitoba, Winnipeg, Manitoba, Canada*

[*]*Corresponding Author: Jillian.SeniukCicek@umanitoba.ca*

ABSTRACT

In this study, a rapid grey and academic literature scoping review was conducted to investigate how Indigenous Knowledges, perspectives, values and cultures are being incorporated into engineering education in several colonialized countries. The findings were used to make recommendations on advancing the Biosystems Engineering curriculum at the University of Manitoba to educate future engineers who have the cultural capacity to work ethically, respectfully, and reciprocally in engineering practice and partnership with Indigenous Peoples and communities. The study was spurred in part by the Truth and Reconciliation Commission of Canada's 94 Calls to Action. In collaboration with Indigenous Peoples, calls for integrating Indigenous knowledge and teaching methods into classrooms and building student capacity for intercultural understanding, empathy, and mutual respect. Sources for this review were gathered from Canada, the United States, Australia, and New Zealand, countries that share a similar history of European colonization and are developing methods for curricular change. The findings demonstrated that incorporation of Indigenous Knowledges perspectives in engineering education can be organized into five main themes: *1. capacity building for engineering educators, 2. consultation and collaboration with Indigenous Peoples and communities, 3. coalescing dominant, Indigenous and engineering perspectives, 4. preparing students for professional practice with Indigenous Peoples,* and *5. developing a new curriculum*. By incorporating these recommendations, engineering educators will help create an educational environment where Indigenous Peoples and their ways of knowing, being and doing have space alongside Western and engineering worldviews. This will prepare engineering students for culturally sensitive and ethically sound professional practice and support the students who will see themselves reflected in Biosystems Engineering.

KEYWORDS

Indigenous Knowledges, decolonizing knowledge education, TRC Calls to Action, rapid scoping review

RESUME

Dans cette étude, une revue rapide de la littérature grise et didactique a été menée afin d'examiner comment les connaissances, les perspectives, les valeurs et les cultures autochtones sont incorporées dans l'enseignement du génie dans plusieurs pays colonisés. Les résultats ont été utilisés pour formuler des recommandations sur la façon de faire progresser le programme d'études en génie des biosystèmes à l'Université du Manitoba afin de former de futurs ingénieurs qui ont la capacité culturelle de travailler dans la pratique du génie de façon éthique, respectueuse et réciproque, et en partenariat avec les peuples et les communautés autochtones. Cette étude a été motivée en partie par les 94 appels à l'action de la Commission de vérité et réconciliation du Canada qui, en collaboration avec les peuples autochtones, préconise l'intégration des connaissances et des méthodes d'enseignement autochtones dans les salles de classe ainsi que le renforcement des capacités étudiantes en matière de compréhension interculturelle, d'empathie et de respect mutuel. Les sources de cette revue ont été recueillies au Canada, aux États-Unis, en Australie et en Nouvelle-Zélande, des pays qui partagent une histoire similaire de colonisation européenne et qui élaborent des méthodes pour modifier les programmes scolaires. Les résultats ont démontré que l'incorporation des connaissances et des perspectives autochtones dans la formation en ingénierie peut être organisée en cinq thèmes principaux : *1. le renforcement des capacités des formateurs en ingénierie, 2. la consultation et la collaboration avec les peuples et les communautés autochtones, 3. l'unification des perspectives dominantes, autochtones et d'ingénierie, 4. la préparation des étudiants à la pratique professionnelle avec les peuples autochtones, et 5. l'élaboration d'un nouveau programme d'études*. En intégrant ces recommandations, les formateurs en génie contribueront à créer un environnement éducatif où les peuples autochtones et leurs façons de connaître, d'être et de faire auront leur place aux côtés des visions du monde occidental et du génie. Cela préparera les étudiants en génie à une pratique professionnelle culturellement et éthiquement respectueuse, et favorisera la rétention des étudiants autochtones qui se reconnaîtront dans le génie des biosystèmes.

MOTS CLÉS

génie des biosystèmes, connaissances autochtones, décolonisation de l'enseignement du génie, appels à l'action de la CVR, examen rapide de l'étendue des connaissances

CITATION

Ruta, A., J. Seniuk Cicek, A. Mante, M. Speare and R. Herrmann. 2021. **Ten calls to action to integrate Indigenous Knowledges and perspectives into the Biosystems Engineering Program at the University of Manitoba.** Canadian Biosystems Engineering/Le génie des biosystèmes au Canada 63: 9.1-9.17. https://doi.org/10.7451/CBE.2021.63.9.1

INTRODUCTION

Residential schools were established in Canada to erase Indigenous Peoples, Knowledges, languages, and cultures, one of the long reaching arms of cololong-reachingridge (2010). The attempt to eradicate Indigenous Peoples and their ways of knowing, doing and being created the perception that Indigenous Knowledges are inferior and opposed to Western science (Battiste 2002). In 2008, the Truth and Reconciliation Commission (TRC) of Canada was struck to document the experience of Residential School survivors, inform Canadians about the lasting impact of Residential Schools, and encourage understanding, truth and work towards reconciliation between Indigenous Peoples and Canada. The TRC released 94 Calls to Action in 2015 detailing the steps necessary for governmental, legal, media, churches, business, and educational systems to achieve reconciliation. As a result, Canadian universities are working in collaboration with Indigenous Peoples to address the Calls to Action by making space for Indigenous Peoples, Knowledges, perspectives, and values in post-secondary education. This movement, and the importance of Indigenous Knowledges and perspectives, are beginning to be seen and understood in engineering education (Seniuk Cicek et al. 2020; Friesen and Herrmann 2018).

In Western engineering and science, students are often taught to evaluate and solve problems through a purely technical and objective lens (Mejia and Paula 2019; Reconciling Ways of Knowing Forum 2020). The current model of teaching engineering generally progresses linearly from technical and theoretical information to an applied project in the final year; however, this model may not be the most effective way to prepare students for the ever-changing and complex environment of professional practice (Foster and Jordan 2014). Real-world problems are never constrained by only technical factors and include social, political, and non-technical aspects (Baillie 2011). There is an increasing number of "wicked" problems globally (Foster and Jordan 2014). There is the opportunity to advance engineering education to equip students to address these problems in their professional practice effectively, which are essential within the engineering community (Leigh et al. 2014; Bang and Medin 2010; Rhamdhani et al. 2009), as diverse perspectives are more likely to produce multiple creative, and thereby, sustainable solutions (Murray et al. 2019). Indigenous Peoples present us with the opportunity to learn and employ a more holistic and contextual approach to solving problems (Mejia and Paula 2019; Reconciling Ways of Knowing Forum 2020). Indigenous Peoples have been practicing engineering for a millennium and developed technologies that we still use today (Herrmann 2019). Positioning engineering students to learn about and from Indigenous Peoples and local Indigenous communities will produce a new generation of well-rounded, culturally competent professionals better equipped to work with Indigenous Peoples and tackle today's wicked problems.

Integrating Indigenous knowledges and perspectives into engineering education will also contribute to the recruitment and retainment of Indigenous students in engineering programs. Barriers such as lack of representation of Indigenous worldviews in the engineering curriculum and a lack of Indigenous engineering role models have been identified in preventing Indigenous students from beginning and completing engineering programs (Foster and Jordan 2014; Leydens et al. 2017; Colston et al. 2019; Goldfinch and Kennedy 2013; Wiseman and Herrmann 2018). In Manitoba, for example, 18% of the population identifies as Indigenous (Statistics Canada 2017). However, only 8.5% of the student population at the University of Manitoba and 6% of students in the Price Faculty of Engineering identify as Indigenous (University of Manitoba 2020; Friesen and Herrmann 2018). The Engineering Access Program, ENGAP, plays an important role in increasing the number of Indigenous engineers in Manitoba, retaining and graduating 140 Indigenous students over the past 35 years (University of Manitoba 2020), but more must be done. Understanding how specific Indigenous Peoples and communities relate to and practice engineering is also a way to help develop curricula that will support recruiting and retaining Indigenous students.

POSITIONALITIES, MOTIVATION & OBJECTIVES

The authors are three white woman settlers, including a recent engineering graduate, an assistant professor, a science and technology librarian, one black woman who is a post-doctoral fellow and originally from Ghana, and one Métis professional engineer. They are all living and working on the traditional lands of the Anishinaabeg, Cree, Oji-Cree, Dakota, and Dene Peoples and Homeland of the Métis Nation in Winnipeg Manitoba, Canada. This research began when the first author was completing her final semester as an engineering student in the Biosystems Engineering department in the Price Faculty of Engineering at the University of Manitoba.

The Biosystems Engineering program encompasses a wide range of courses designed to educate students to practice engineering within biological systems. Previously accredited as an Agricultural Engineering program, it has expanded to include biomedical, environmental, and bioresource specializations (University of Manitoba 2020). Biosystems Engineering students complete the same first-year preliminary courses as Mechanical, Electrical, Civil, and Computer engineering students before moving on to their specialized courses in the Biosystems Engineering program in the second year. The program comprises 45 courses: 35 core courses and 10 electives divided into four categories (i.e., two science electives, three Biosystems Engineering design electives, three complementary studies electives, and two free electives). Presently, there is no mandatory Indigenous content in the Biosystems Engineering program.

The first author's exposure to Indigenous culture and communities was voluntarily gained outside of the

Biosystems Engineering curriculum through work experience and co-op positions. The first author worked for a Science, Technology, Engineering, and Math (STEM) outreach program that delivers hands-on education to underrepresented youth throughout her engineering education. She was educated about Indigenous history, ceremonies, teaching methods, and scientific Knowledges before delivering camp programming in First Nations communities across the province. She was immersed in new cultures and gained an appreciation for Indigenous science and engineering Knowledges and principles. She realized that education about and from Indigenous perspectives was missing from her engineering education. This research addresses that void.

We argue that Biosystems Engineering is uniquely suited to introduce Indigenous Knowledges and perspectives into the curriculum. Biosystems Engineering students learn to solve complex problems with high regard for sustainability and the health of all organisms within the environment in which they are working. The emphasis of engineering with respect for biological systems could be reflective of the values of respect for holistic, relational approaches shared by many Indigenous cultures. This biological focus offers a unique opportunity to bridge Western, engineering, and Indigenous Knowledges and perspectives.

The objectives of this study are twofold: (i) to conduct a rapid grey and academic literature scoping review to investigate how Indigenous Knowledges, perspectives, values and cultures are being incorporated into engineering education in colonialized countries; and (ii) to make recommendations on how to advance the Biosystems Engineering curriculum at the University of Manitoba specifically, and engineering programs generally, to recruit and retain more Indigenous students and educate future engineers who have the cultural capacity to work ethically, respectfully, and reciprocally in engineering practice and in partnership with Indigenous Peoples and communities.

METHODOLOGY

A rapid grey and academic literature scoping review was designed to investigate how Indigenous Knowledges, perspectives, values, and cultures are being incorporated into engineering education in Euro-colonialized countries. This methodology was used as in Canada, incorporating Indigenous ways of knowing, being and doing into engineering education is generally an emerging movement with initiatives not widely known (Seniuk Cicek et al. 2020). A scoping review helps to determine the "breadth and describe characteristics of literature in complex and understudied research areas" rather than "answer[ing] focused questions from quality assessed studies" (Chandna et al. 2019 p. 23). These initiatives are often found to be disseminated outside of traditional academic publications. A grey literature review works to obtain "information produced outside of traditional publishing and distribution channels" (Chandna et al. 2019 p. 41). The methodology is further classified as a rapid scoping review because only one author reviews the literature within a short period (Ganann et al. 2010).

Method

An unsystematic literature review was conducted from February to March 2020. The review was then updated using systematic searches by the first author in January 2021. A rapid scoping review of grey and academic literature as designed by Arksey and O'Malley (2005) and adapted by Levac et al. (2010) (as informed by Chandna et al. 2019) was conducted. Scopus, ProQuest Dissertations and Theses, Web of Science Core Collection, ERIC, and Engineering Village (Compendex) were searched with the key terms in the title, abstract, and keywords. Searches were limited to publication years from 2000 to current. Search strategies were adjusted for individual databases, and relevant subject headings were included when available. Keywords were truncated to allow for singular and plural forms and alternative endings (see Table 1 for the list of key terms).

In addition, between January 18th and 23rd 2021, the conference proceedings of the American Society for Engineering Education (ASEE) and the Canadian Engineering Education Association (CEEA-ACEG) were searched using the term *Indigenous Knowledge*. The Australian Association for Engineering Education (AAEE) conference proceedings were searched using the terms *Indigenous Knowledge, Indigenous,* and *Aboriginal*.

Table 1. Key terms used in search strategies of bibliographical data bases.

Field	Education	Perspective	People	
engineer*	content*	cultur*	aborig*	maori*
	course*	knowledge*	American Indian	metis
	curricula	perspective*	amerind*	Native Alaskan
	curriculum	value*	eskimo*	Native American
	educat*	worldview*	First Americans	Native Canadian
	program*		First Australians	Native Peoples
			First Canadians	Torres Strait Islander
			First Nations	tribal
			indig*	tribe
			inuit*	tribes

Google Scholar was searched using the following strategies: "*Indigenous Knowledge" and "engineering curriculum", "engineering curriculum" AND (indigenous OR aboriginal OR "american indian"),* and *allintitle: engineering AND (indigenous OR aboriginal OR "american indian").*

The first 50 results from each of the three searches were included. Additional literature was gathered from an Indigenous Knowledges Research project sponsored by the NSERC Design Chair in Engineering in the Price Faculty of Engineering at the University of Manitoba and from the second author's research work. All the results were screened by the first author on the literature review software, Rayyan. The inclusion criteria are as follows:

- published after 2000;
- describes the education of post-secondary engineering students or educators in Canada, the United States, Australia, or New Zealand as they share a similar history of Indigenous populations colonized by European settlers; and
- discusses Indigenous knowledge or perspectives in relation to said education.

See Fig. 1 for graphical description of review methodology.

Forty-three pieces of grey and academic literature met the criteria for this study and were analyzed for this rapid scoping review. Most records originated from Australia (43%), followed by Canada (36%), the United States (19%) and New Zealand (2%). Grey literature made up most of the records reviewed including conference proceedings, theses and dissertations, reports, news articles, educational guides, and an online dialogue. The academic literature included journal articles.

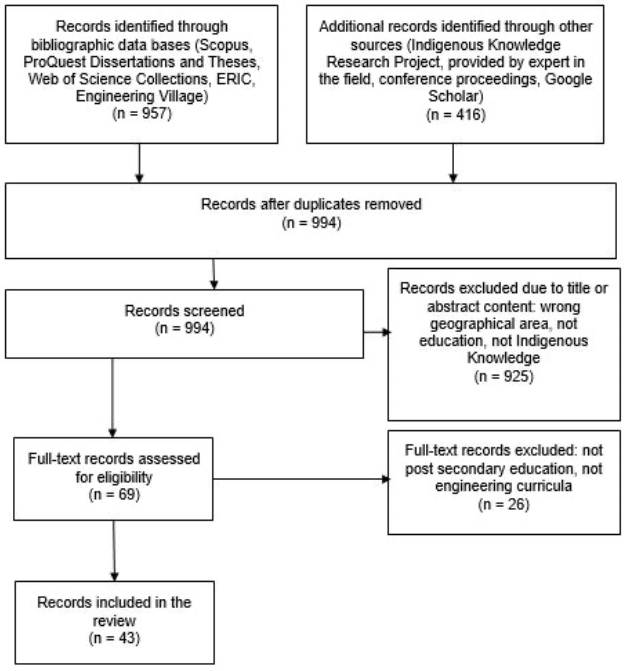


Fig. 1. Process of gathering records for the review.

From these 43 texts, five themes of incorporating Indigenous Knowledges and perspectives into engineering education emerged: 1. *capacity building for engineering educators; 2. consultation and collaboration with Indigenous Peoples and communities; 3. coalescing dominant, Indigenous and engineering perspectives; 4. preparing students for professional practice with Indigenous Peoples*; and 5. *developing a new curriculum*.

Of the 43 pieces of literature reviewed, 34 discussed tangible Indigenous initiatives. There was no formal evidence reported on the success of the various initiatives, but rather descriptions of future work intended to determine their impact. In some cases, there was preliminary feedback from participants that suggested positive outcomes such as a greater understanding of intercultural themes and multiple perspectives (e.g., Sprowles et al. 2019; Steele et al. 2020), an understanding of how cultural differences influence design (e.g., Benning et al. 2015), and the development of trusting relationship with an Indigenous community (e.g., Seniuk Cicek et al. 2019b).

A list of this literature is found in Table 2, organized by the five themes that emerged from the findings (*note*: some of the literature is representative of more than one theme). Initiatives are classified as advanced (A), implemented (I), or proposed (P). Advanced is characterized as multiple occurrences of the initiative. For example, *A Beginners Guide to Incorporating Aboriginal Perspectives in Engineering Curricula* (Kennedy et al. 2016) is classified as *advanced* because recent initiatives in Australia (e.g., Goldfinch et al. 2016b; Kutay and Leigh 2017a; Prpic and Bell 2018) were developed using this guide. Initiatives characterized as *implemented* have been implemented at least once and include literature that describes plans to continue that initiative. *Proposed* initiatives had not been implemented at the time they were described in the literature.

Only the first two themes, 1. *capacity building for engineering educators* and 2. *consultation and collaboration with Indigenous Peoples and communities* are represented by all four countries scoped in this review. Australia is the only country with Indigenous initiatives in all five themes. Canada is represented in all but the theme, *3. coalescing dominant, Indigenous and engineering perspectives*. The literature is discussed by themes in the following sections. For consistency in this paper, the authors will use the term "Indigenous" to refer to the First Peoples, Métis and Inuit people on Turtle Island in Canada, and to the original peoples of Australia, New Zealand and the United States, as it is the accepted terminology in Canada presently.

Capacity building for engineering educators

Non-Indigenous engineering educators who will be teaching a new Indigenized curriculum need to take the initiative to educate themselves about Indigenous cultures, social structures, and legal and political systems before consulting with Indigenous communities. Interviews with non-Indigenous engineering educators in Australia

Table 2. Indigenous initiatives in the literature (n=34) organized by theme and stage: advanced (A), implemented (I), or proposed (P).

Theme	Country	Citation	Stage
1. Capacity building for engineering educators	AUS	Goldfinch et al. 2016b	P
		Kennedy et al. 2016	A
		Leigh et al. 2014	I
		Kutay and Leigh 2017b	I
	CAN	Seniuk Cicek at el. 2019c	I
		UBC 2020	I
		Harrison et al. 2018	I
		Reconciling Ways of Knowing Forum 2020	I
	NZ	Hughes et al. 2018	I
	USA	Lord et al. 2019	I
2. Consultation and collaboration with Indigenous Peoples and communities	AUS	Kennedy et al. 2016	A
		Goldfinch and Kennedy 2013	I
		Prpic and Bell 2018	I
	CAN	Mante et al. 2019	I
		Seniuk Cicek at el. 2019b	I
	NZ	O'Sullivan and Cochrane 2009	A
	USA	Mehta et al. 2007	I
		Benning et al. 2015	I
		Sprowles et al. 2019	I
3. Coalescing dominant, Indigenous and engineering perspectives	AUS	Kennedy et al. 2016	A
		Kutay and Leigh 2017a	P
		Leigh et al. 2014	P
	USA	Foster and Jordan 2014	P
4. Preparing students for professional practice with Indigenous Peoples	AUS	Baille 2011	P
		Katz 2020	P
	CAN	Johnson 2016	P
		Johnson 2020	P
	USA	Momo et al. 2020	I
5. Developing a new curriculum	AUS	Leigh et al. 2014	P
	CAN	Friesen and Herrmann 2018	I
		Fitz Gerald 2015	I
		Frey et al. 2018	I
		Latimer 2020	I
		Eikenar 2018	P
		Steele et al. 2020	I
		Seniuk Cicek at el. 2019a	I
	USA	Grommes et al. 2004	I

highlighted the cognitive, affective, and conative components of the educators' attitudes towards Indigenous culture and perspectives and their experiences with Indigenous Peoples (Goldfinch et al. 2017). They found that participants with more experience with Indigenous Peoples and communities had less defined assumptions of Indigenous perspectives in engineering and understood the need for more education of non-Indigenous educators, while those with less personal experience expressed misguided beliefs. A workshop at the Australian Conference for Engineering Education entitled *Shifting Perspectives-Changing Direction: Integrating Aboriginal Engineering into Modern Engineering Curricula* (Leigh et al. 2015) was presented to engineering educators to help them introduce Indigenous perspectives into their curriculum. Goldfinch et al. (2016a) later interviewed 10 of the participants, all of whom were non-Indigenous, and learned that they experienced a sense of distance from Indigenous People and culture, were not enthusiastic about progressing further than adding Indigenous content, and were unclear about the value that Indigenous perspectives would bring to their curricula even though they expressed interest in pursuing this initiative. These findings demonstrate that the attitudes and assumptions of non-Indigenous educators must be understood to provide them with the education and experience necessary to deliver a curriculum with Indigenous Knowledges and perspectives.

In Canada, examples of faculty education include a series of workshops at the University of Manitoba that were designed to facilitate an understanding of the relationship between Indigenous culture and engineering (Seniuk Cicek et al. 2019c), and a four-part facilitated dialogue series hosted by the University of British Columbia for students and faculty that began with presentations by Indigenous

Peoples to examine *Truth and the Role of Engineers in Decolonization* (University of British Columbia 2020). In British Columbia, Indigenous scholars collaborated to develop a guide to help administrators and education leaders Indigenize postsecondary institutions, with a focus on supporting Indigenous students and valuing Indigenous world views and ways of knowing (Harrison et al. 2018). This guide includes references to relevant engineering education resources such as, *Indigenization in the time of pipelines*, a presentation from the 2016–2017 Weweni Indigenous Scholars Speaker Series, University of Winnipeg (Vowel 2017).

The outcomes of a project report in Australia by Goldfinch et al. (2016b) included a model for engineering curricula that accommodates various perspectives, an elective course that relates Indigenous perspectives to local engineering projects, and a model for engineering faculty to engage with Indigenous communities. Another outcome of the project was the guide designed for engineering educators mentioned previously, *A Beginners Guide to Incorporating Aboriginal Perspectives into Engineering Curricula* by Kennedy et al. (2016), which discusses five ways to incorporate Indigenous perspectives into the curricula. Kennedy et al. (2016) recommend: 1. *start with a new philosophy,* by focusing on the differences and assets in knowledge systems as opposed to focusing on deficits, such as social and health indicators, between the dominant and Indigenous cultures*;* 2. *explore engineering from three perspectives*: dominant, Indigenous, and engineering*;* 3. *consider an Aboriginal worldview* by recognizing Australian Indigenous philosophies such as country, kinship, culture, journey, and connectedness; 4. *engage with Aboriginal People and their communities;* and *5. tailor the learning environment* to include Indigenous content, teach using Indigenous methods, and facilitate experiences between non-Indigenous students and Indigenous community partners.

There are also online dialogues, courses and conference workshops that have been offered to learn more about incorporating Indigenous perspectives into curricula, such as *Reconciling Ways of Knowing Forum* (2020), *Master Class - Indigenous engineering, a pathway to reconciliation/Intercultural competence?* (Leigh et al. 2014); *He Awa Whiria: Weaving Indigenous and Western Perspectives and Creating Inclusion in Australian Engineering Education* (Hughes et al. 2018); *Validating Storytelling for Indigenous Knowledge Teaching* (Kutay and Leigh 2017b); and *Special Session: Starting a Dialogue on Decolonization in Engineering Education* (Lord et al. 2019).

Consultation and collaboration with Indigenous Peoples and communities

To Indigenize an institution, program, or curriculum, administrators and educators must primarily consult and collaborate with local Indigenous community members. However, Goldfinch et al. (2017) reported that educators are unsure of how to initiate these crucial relationships. *A Beginners Guide to Incorporating Aboriginal Perspectives into Engineering Curricula* from the University of Wollongong, Australia teaches about the five "rights" of engaging with Indigenous communities: *1. Right people; 2. Right place; 3. Right language; 4. Right time;* and *5. Right way* (Kennedy et al. 2016). Goldfinch and Kennedy (2013) described the four "don'ts" of engaging with Indigenous communities as: *1. Consultation for the wrong reasons; 2. Creating unsustainable initiatives; 3. A deficit view of Indigenous culture;* and *4. Pan Indigenizing.* The five "rights" and four "don'ts" aim to help educators build meaningful relationships with local Indigenous communities and ensure educators do not repeat past mistakes, which have led to distrustful relationships.

In the literature concerning consultation, authors reiterated the warning against "pan-Indigenizing", defined as grouping all Indigenous cultures and communities together as one (Goldfinch and Kennedy 2013). They emphasized that communication and relationships with each Indigenous community will differ, centred in place. Therefore, no approach for bringing Indigenous Knowledges and perspectives should be the same for any program because programs are in different places. Different locations indicate distinctive communities, and each will have their own languages, cultures, social structures, legal and political systems, and communication practices (Goldfinch and Kennedy 2013). The changes needed to Indigenize curriculum will be and should be unique to each program, dependent on the consultation with the Indigenous Peoples and their communities that are located in that place. This view that educators must collaborate with local Indigenous Peoples to develop an engineering curriculum that is representative of their community is prevalent throughout the literature, and several studies have reported on these collaborative initiatives (e.g., Mante et al. 2019; Goldfinch and Kennedy 2013). Mante et al. (2019) designed a study to assess the impact on students' learning after a lecture about consultation with Indigenous communities during infrastructure development from the perspective of a local Elder. This work is presently underway, but preliminary findings demonstrated the profound impact the Elder's visit had on the students who agreed to participate in the study (Thomsen et al. 2021; Kilada et al. 2021).

Another focus of collaborative initiatives describes including Indigenous communities as stakeholders in design or capstone projects. For example, the College of Engineers at Rowan University in the USA has incorporated an Engineers Without Borders project into their curriculum and has previously worked with the Cheyenne River Indian Reservation community to construct a fish hatchery (Mehta et al. 2007). At the University of Wollongong (UOW) in Australia students complete a community-based design challenge in a first-year course entitled *Engineering Design and Innovation* to be implemented in the Sandon Point Aboriginal Tent Embassy (SPATE), which must align with SPATE cultural values and the City of Wollongong regulations (Goldfinch and Kennedy 2013). Goldfinch and

Kennedy (2013) described instilling SPATE community values into UOW curricula, and students practicing consultation with Indigenous Peoples as potential benefits of this project.

Another Australian university, the University of Melbourne, offers an on-country learning experience with the Gunditjmara community where students develop proposals for projects on the Budj Bim National Heritage Landscape (Prpic and Bell 2018). The University of Manitoba in Canada offered an elective design-build course in partnership with Shoal Lake 40 First Nation (Seniuk Cicek et al. 2019b). Students worked alongside community members to design and build a shelter for feasting (Seniuk Cicek et al. 2019b). Similarly, students and faculty from the South Dakota School of Mines and the Oglala Lakota College in the USA collaborated with the Pine Ridge Indian Reservation to design a sustainable food production system for their senior capstone course (Benning et al. 2015). They created a trusting relationship with the stakeholders and learned the important lesson that differences between mainstream American and Lakota worldviews can significantly impact a design (Benning et al. 2015).

Humbolt State University in the USA offers four Place Based Learning Communities specific to different STEM disciplines (including Environmental Resource Engineering) for first year students, which include courses and high impact practices focused on Native American culture, ways of knowing, and issues facing the local Indigenous communities (Sprowles et al. 2019). An outcome of the four-term compulsory research project for Natural Resource Engineering students at the University of Canterbury in New Zealand is engaging with Indigenous Peoples and cultures and relating engineering projects to principles in the Treaty of Waitangi (O'Sullivan and Cochrane 2009). Students were exposed to Indigenous culture and learned about Indigenous Knowledges and perspectives from their community partners. These courses provide a unique experience for students and the opportunity to gain skills and knowledges they would not gain in a typical classroom setting.

Coalescing dominant, Indigenous and engineering perspectives

An individual's definition of engineering influences the way it is taught and learned (Foster and Jordan 2014). Therefore, to successfully incorporate Indigenous Knowledges and perspectives into the curriculum, students and educators must be open to considering new perspectives. Instead of replacing one's way of knowing and learning STEM with a Western perspective, Bang and Medin (2010) demonstrated the efficacy of Indigenous youth utilizing their own ways of knowing to fully harness their learning potential. With the help of their educators, engineering students – both Indigenous and non-Indigenous - could also benefit from learning STEM from Indigenous knowledge systems (Reconciling Ways of Knowing Forum 2020).

A framework proposed by researchers in Australia is "exploring engineering from three perspectives" (Kennedy et al. 2016), which encourages seeing engineering at the intersection of the dominant/Western perspective, the engineering perspective, and Indigenous perspectives (Kennedy et al. 2016; Kutay and Leigh 2017a; Leigh et al. 2014; Foster and Jordan 2014). As students' progress in their engineering education, they were reported to develop a new set of ideologies exclusive to engineering (Baillie 2011). Kennedy et al. (2016 p.13) described engineers as "problem solvers utilising scientific principles and the engineering method to develop technical solutions for particular purposes". This definition is shared by Indigenous Peoples and non-Indigenous people, and yet engineering is taught through the dominant/Western/ Eurocentric perspective. To incorporate Indigenous Knowledges into the curriculum, educators and students must learn from Indigenous Peoples for a true representation of Indigenous engineering. Foster and Jordan (2014) compared the Diné and engineering philosophy of learning by answering questions like "What types of problems are of concern?", "What is the method used to solve problems?", and "How are decisions made?" from each perspective. The comparison demonstrated how the Diné learning philosophy has the potential to complement the Western engineering philosophy through practices like considering sociocultural relationships when making decisions.

Kennedy et al. (2016) suggested their students examine real-world examples by considering the possible outcomes of a project from the three perspectives – Indigenous, Western/dominant, and engineering. It was important for Kennedy et al. (2016) to separate the three perspectives to validate Indigenous engineering achievements that may not be familiar to those with dominant engineering perspectives. Leigh et al. (2014) advised acknowledging multiple pathways to a solution and highlighting that Indigenous engineering solutions are as complex as Western engineering solutions, and each should be valued equally. They emphasized that Indigenous values, such as respect for the land and all beings in nature can inform Western-led engineering projects to proceed with more consideration for sustainability (Leigh et al. 2014). Kutay and Leigh (2017a) also advised educators to emphasize the similarities and differences between Indigenous engineering practices and Western engineering practices to expand students' cultural awareness.

Preparing students for professional practice with Indigenous Peoples

Evidence from Australia demonstrated that engineering educators and engineering curricula have not adequately prepared engineering graduates to work in professional practice in terms of social, cultural, political Indigenous awareness. Engineering students in their final year at the University of Wollongong researched the practices engineering companies used to address Indigenous culture and heritage in their project planning relating to 10 local projects as part of the course *ENGG456 Engineering Project* (Goldfinch et al. 2014). They found that the best

results were due to outsourcing community engagements, suggesting the need for more Indigenous awareness education for engineering students. Hollis and Goldfinch (2017) also surveyed Australian engineering graduates in their first years of the industry to assess their experience, training, and formal education of Indigenous Cultural Heritage. They found that some students took additional courses to learn about Indigenous Cultural Heritage, but it was not a requirement, therefore most graduates lacked the training and confidence to collaborate with Indigenous community stakeholders once in the industry (Hollis and Goldfinch 2017).

At Queen's University in Canada, Johnson (2016) determined through surveys that although mining engineering students were eager to address the negative perceptions of mining by respecting the environment and communities in which they worked, they lacked understanding and appreciation for cultural views other than their own. Johnson (2016) proposed three concepts, 1. *Awareness and Acknowledgement of Different Forms of Knowledge*; 2. *Recognition that Value Systems are a Function of Culture*; and 3. *Respect for Varied Perceptions of Social Wellbeing and Quality of Life* be introduced into the curriculum to better prepare mining students for professional practice in Indigenous communities. Johnson (2020) also provided a theoretical framework for shifting engineering culture towards valuing intercultural competence. In Australia, Katz (2020) agreed that engineering students in the extractive fields should be better prepared to collaborate with Indigenous Peoples, as Indigenous Peoples and communities are often stakeholders in extractive industry projects. To address the lack of social awareness education in the engineering curriculum, Baillie (2011) consulted a multidisciplinary team of academics to develop case studies for a proposed curriculum in which students will examine the intersection of engineering and Indigenous studies, history, law, anthropology, Asian studies, education, and philosophy. Momo et al. (2020) from the USA suggested incorporating *Culturally Relevant/Responsive Pedagogy, Culturally Sustainable Pedagogy, and Indigenous Pedagogy* into existing courses (statics, thermodynamics, and electrical circuits) and adding new courses such as *User Centered Design,* and *Engineering for Social Justice* to change the culture of engineering education and enhance the skill set of future engineers in professional practice.

Developing a new curriculum

There have been multiple methods used to incorporate Indigenous Knowledges and perspectives in curricula reported in the literature. A study by Seniuk Cicek et al. (2020) had engineering educators from 24 Canadian accredited engineering programs and four Engineering organizations self-report on how they have started or are involved in Indigenous initiatives work in varying ways. Of these, 17 institutions demonstrated engagement in curricular development. At the University of Manitoba in Canada, the Price Faculty of Engineering proposed to restructure three core courses that focus on engineering design and professional practice (*Design in Engineering* (a first-year course), *Engineering Economics*, and *Technology, Society and the Future*) to include content related to local Indigenous design principles, perspectives, history, and community structure and processes (Friesen and Herrmann 2018). These courses were chosen because they highlight the ways in which engineers often interact with other professionals and utilize shared concepts to benefit society. Suggested content includes analyzing Indigenous designs, discussing the contrast between Western and Indigenous concepts, and using case studies to learn about Indigenous society and governance. In two of these courses, Indigenous Elders, Knowledge Keepers, and academics are invited to speak with students about Indigenous cultures, ways of knowing, being and doing, and the impact of engineering on Indigenous communities and ways of life (Thomsen et al. 2021; Kilada et al. 2021).

Analysis of Indigenous engineering design concepts and technologies is also taught in first year design at the University of Saskatchewan in Canada (Fitz-Gerald 2015). The University of Saskatchewan redesigned their entire first year engineering curriculum to develop a more diverse skill set in their graduates, which includes creating an appreciation for Indigenous perspectives in engineering (Frey et al. 2018). Australian researchers have redeveloped the *Engineering Design and Innovation* course at the University of Wollongong to examine the relationship between the three perspectives – Indigenous, dominant, and engineering – in relation to the artefact space, which is defined as the intersection of these perspectives (Leigh et al. 2014). Similarly, a professor at Concordia University in Canada worked with Donna Kahérakwas Goodleaf, a citizen of the Kanien'kehá:ka nation, Director, Decolonizing Curriculum and Pedagogy in the Office of the Provost and Vice-President, Academic Affairs at Concordia University to change the curriculum in *Impact of Technology on Society* by discussing design justice and including readings from Indigenous authors whose communities were affected by engineering projects (Latimer 2020). At the University of British Columbia-Okanagan School of Engineering, Eikenaar (2018) proposed the development of course based modules focused on case studies as a delivery method for Indigenous content into the engineering curriculum.

A similar method is used at Carleton University. Eight modular Indigenous learning bundles on a range of topics such as *Indigenous Environmental Relations, Engaging with Indigenous Communities,* and *Indigenous Law and Conceptions of Human Rights* are available to help educators introduce Indigenous content and perspectives from Indigenous Knowledge Keepers into their existing courses (Steele et al. 2020). A first-year engineering course used the bundle *First Peoples: A Brief Overview* to build a foundation of Indigenous awareness and a third-year electrical engineering course used *Indigenous Environmental Relations*. Seniuk Cicek et al. (2019a),

guided by Anishinaabe/Metis/Dakota Indigenous initiatives educator, Leah Fontaine, reinterpreted the 12 CEAB (Canadian Engineering Accreditation Board) graduate attributes (i.e., the engineering competencies required of all engineering students graduating from CEAB accredited institutions in Canada) and the pillars of engineering sustainability with the Anishinaabe Sacred Hoop as the framework. Findings showed that "the Spirit aspect needs attention in engineering education in order to develop "the whole engineer", and through this work "conditions for transformation" (Lange, 2018, p. 295, as quoted in Seniuk Cicek et al. 2019a, p. 8) to balance Western and Indigenous perspectives were revealed (Seniuk Cicek et al., 2019a, p. 8).

Other literature discussed educating engineering students about social and sustainability issues that are reflective of Indigenous Peoples' holistic perspectives and their connection to the land. The American Indian Housing Initiative course at Penn State University in the USA consists of three parts in which students learn about American Indian culture and sustainable building technologies. They also collaborated with tribal members in Montana to design and build a structure and reflect on their experience to improve the course (Grommes et al. 2004). Riley et al. (2006) reported that students in this course were more open to learning and valuing different perspectives and better understood the complexity of sustainable design.

DISCUSSION

Making space for Indigenous Peoples, Knowledges, perspectives, values and cultures in engineering education is an emerging initiative in Canada, the United States, Australia, and New Zealand as reflected in the literature found in this rapid scoping review. Grey literature, especially conference proceedings, represented over half of the findings. As conference proceedings often discuss works in progress and were located at a higher frequency than journal articles, it is not surprising that many initiatives are characterized as emerging. Another indication that Indigenizing engineering curricula is emerging but progressing is the amount of proposed (26%) and implemented (68%) initiatives verse advanced initiatives (6%). Grey or academic literature demonstrating the impact of Indigenous initiatives in engineering education were largely absent from the review.

Initiatives also seem to be at different states of progression geographically. Most of the literature found in this review (43%) originated in Australia, compared to Canada (36%), the United States (19%) and New Zealand (2%), which could indicate further progression towards reconciliation with Indigenous Peoples in engineering education in Australia. This is also reflected in that *Reconciliation Australia*, the national body on reconciliation in Australia, was established in 2001 compared to similar organizations in Canada such as the TRC and *Reconciliation Canada*, which were established in 2008 and 2012, respectively. Further emphasis has been placed on educational institutions to include Indigenous Peoples and their ways of knowing, being and doing in curriculum in Canada since the release of the TRC's Calls to Action in 2015. Seniuk Cicek et al. (2020) demonstrated that there is work being done to address these Calls to Action in engineering institutions across Canada through curricula, faculty education, and making space for Indigenous Peoples and community members in engineering education, but there is much more to do.

Implemented initiatives were concentrated in three of the five themes that emerged in the literature: 1. *capacity building for engineering educators,* 2. *consultation and collaboration with Indigenous Peoples and communities*, and 5. *developing a new curriculum.* These initiatives provide education about or from Indigenous Knowledges and perspectives through one or more courses or workshops. These courses/workshops have created momentum toward Indigenizing engineering education, but more can be done to address the entire curriculum, including more efforts in the themes: *3. coalescing dominant, Indigenous and engineering perspectives;* and *4. preparing students for professional practice with Indigenous Peoples*. Gaudry and Lorenz (2018) describe three categories of Indigenous initiatives, *Inclusion, Reconciliation Indigenization,* and *Decolonial Indigenization*, which range from including more Indigenous students and faculty in postsecondary spaces at one end of the continuum, to creating fundamental changes to current university structures at the other end. This review demonstrated that many engineering institutions are progressing along the spectrum, but a broader uptake of Indigenization initiatives among engineering faculty and educators is needed to pursue the goal of *Decolonial Indigenization.*

Figure 2 demonstrates how the five themes found in this review can be used to build an enhanced engineering education curriculum that makes and keeps space for Indigenous Peoples. The numbers 1 – 5 in Fig. 2 correspond to the five themes that emerged in this grey and academic rapid scoping review and offer a way to assess and prioritize efforts in making space for Indigenous Peoples and their ways of being, knowing and doing in engineering education curricula. However, the conceptualization is meant to be viewed as a dynamic, 'living' curriculum that continually evolves as persistent efforts are put into each aspect in the system. As such, the numbers are not meant as static check boxes and must be continually attended to.

In Fig. 2, capacity building for engineering educators (1) is a primary step because it informs the work with the other themes and continually evolves as educators gain new knowledge and experiences. As engineering educators learn about their colonial history and Indigenous resilience, and about local Indigenous cultures, social, legal and political systems through research, workshops, courses, or other methods (i.e., learning is an ongoing, living process), they should begin to consult and collaborate with Indigenous Peoples and communities (2). Collaboration could result in the development of engineering student projects in partnership with Indigenous Peoples and communities,

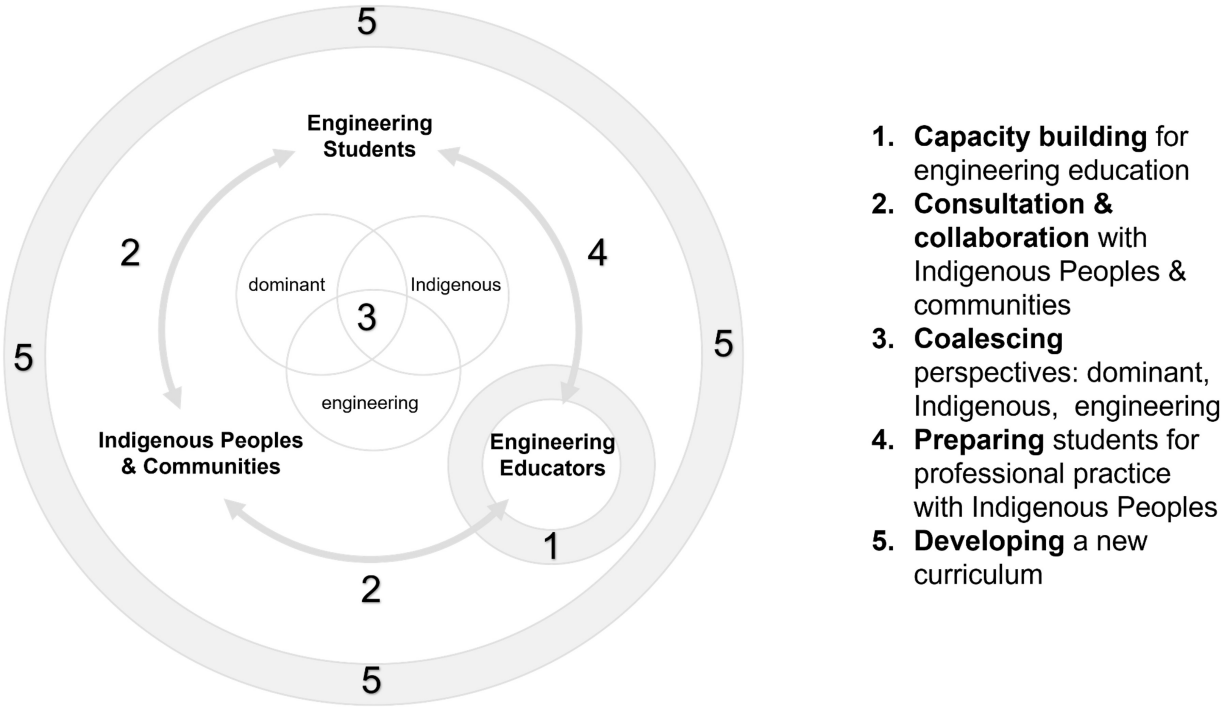


Fig. 2. Conceptual diagram for developing a new curriculum that includes Indigenous Peoples, Knowledges and perspectives in engineering education.

which will enable students to consult and collaborate with Indigenous Peoples (2). These collaborative relationships will inform new course content incorporating the three perspectives – Western/dominant, Indigenous and engineering as offered by Kennedy et al. (2016) – and represented by Venn diagram in the centre of the new curriculum (3). These opportunities and explicit, location-specific curricula delivered by engineering educators will prepare students in good ways for professional practice with Indigenous Peoples and communities (4). The result is a new 'living' curriculum with ethical space for Indigenous Peoples, Knowledges, perspectives, values, and cultures (5). Within this new curriculum there are three stakeholders: Indigenous Peoples and communities, engineering education faculty, and engineering students. Each stakeholder is encouraged to examine their perspectives and consider the perspectives of the other stakeholders as they build capacity and relationships, consult and collaborate, and prepare for and conduct professional practice.

Based on this conceptualization, we offer 10 Calls to Action specifically for the Department of Biosystems Engineering and the Price Faculty of Engineering at the University of Manitoba, and generally for engineering educators in Canada and other colonized countries. These Calls to Action are in the spirit of Wong et al.'s (2020) *10 Calls to Action for Natural Scientists Working in Canada*. They are informed and organized by the five emergent themes from this rapid scoping literature review. They are rooted in the authors' experiences in the Department of Biosystems Engineering and the Price Faculty of Engineering at the University of Manitoba but can and should inform engineering educators in other programs and institutions more broadly.

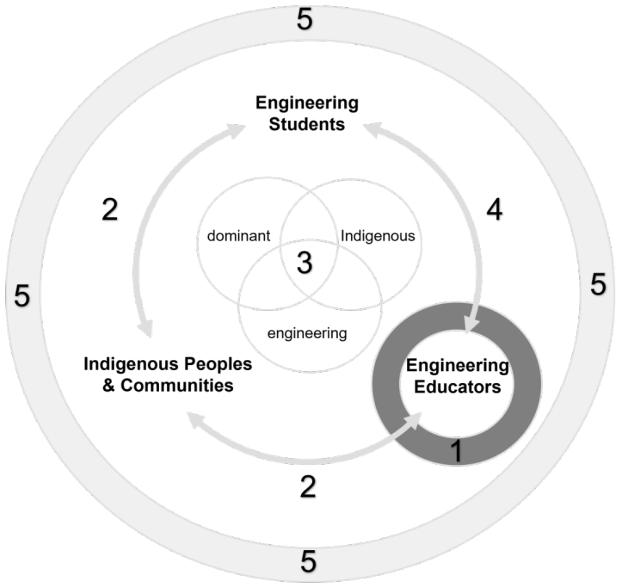
Ten calls to action for engineering educators

1. Offer workshops and professional development opportunities to engage engineering educators in the work of decolonizing and Indigenizing engineering education.

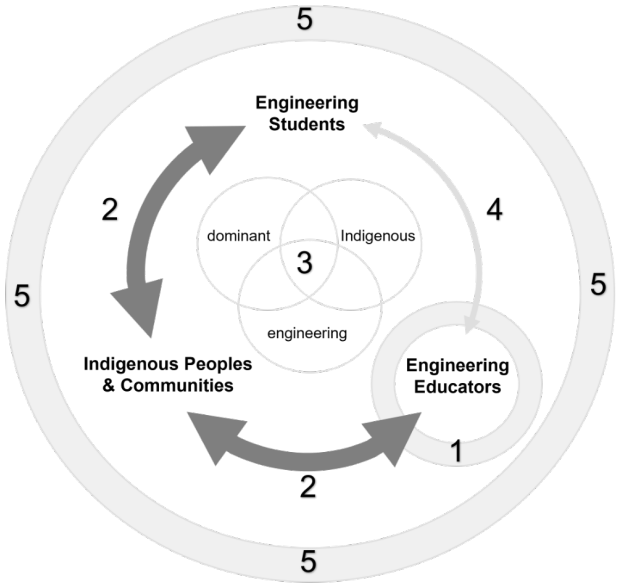
Seniuk Cicek et al. (2019a) worked with an Indigenous educator, Leah Fontaine and the Centre for the Advancement of Teaching and Learning to design a series of engineering-specific workshops/events for faculty. The aim was to cultivate faculty members' understanding of engineering from Indigenous Knowledges and perspectives, and to explore how Indigenous ways of knowing, being and doing can be incorporated into the engineering curriculum in relevant, genuine, and good ways. It is recommended that workshops/events such as these be developed for and offered to engineering stakeholders on an ongoing basis to build engineering educators' capacity to decolonize and Indigenize engineering education. Other opportunities to build capacity include events such as Lunch and Learns and department and faculty retreats.

2. Incentivize Capacity Building.

There are many activities supporting Indigenous ways of knowing, being and doing offered widely across postsecondary institutions (Seniuk Cicek et al. 2020). Examples include Indigenous speakers and events, courses, and workshops, among others. Faculty and staff should be



Theme 1. Capacity building for engineering educators.



Theme 2. Consultation and collaboration with Indigenous Peoples and communities.

incentivized to participate in such capacity building to demonstrate the importance and value of this work (i.e., there should be administrative commitment reflected in measures of reward that acknowledge "cost and utility value" (Matusovich et al. 2014)).

3. Invite Indigenous Elders, Knowledge Keepers, experts, and stakeholders into engineering courses.

Consult and invite Indigenous Elders, Knowledge Keepers and experts into core and specialty engineering courses to share their Knowledges and perspectives, examples of Indigenous ingenuity and technology, and their experiences with Western engineering approaches. Examples for Biosystems Engineering at the University of Manitoba include *Solid Mechanics, Fluid Mechanics, Mechanical Properties of Biomaterials*, as well as courses within the Biosystems Engineering Biomedical, Environmental and Bioresource specializations.

4. Include community engagement courses/projects in engineering curricula.

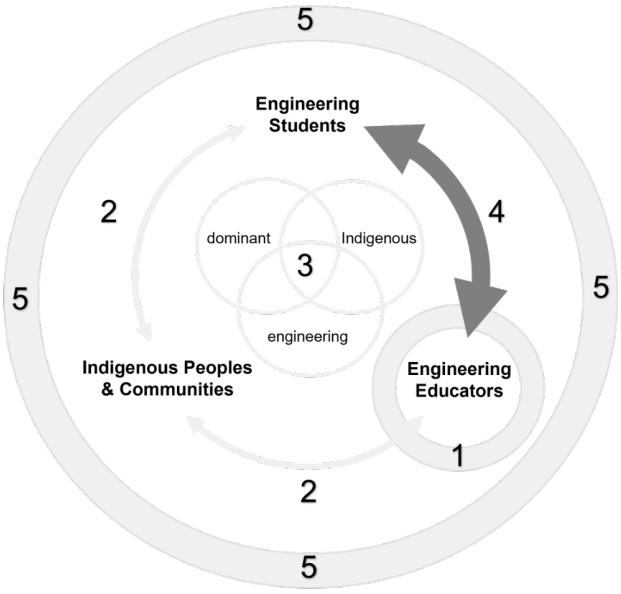
The Price Faculty of Engineering and the Faculty of Architecture at the University of Manitoba currently offer a cross-faculty design-build course in collaboration with Shoal Lake 40 First Nation community (Seniuk Cicek et al. 2019b). It is recommended that all Biosystems Engineering students participate in this course or a similarly developed engagement projects with local Indigenous communities.

5. Introduce students to design projects in collaboration with Indigenous Peoples and communities at the preliminary and mid program years.

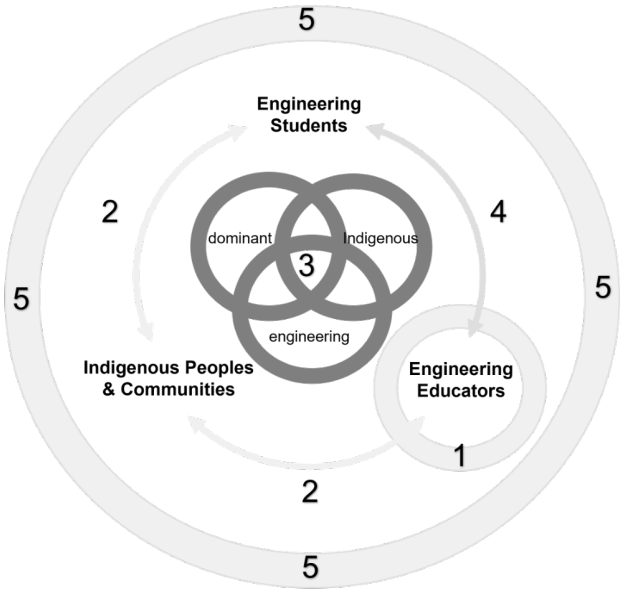
Biosystems Engineering undergraduate students typically register for the capstone course in their final year. In capstone, students work in teams with external clients to design solutions to their clients' challenges. This may be the first-time students work with professionals to develop a working prototype for a real problem. Students gain experience with professionalism, communication, and constraints such as funding, policy, and strict deadlines. It would be beneficial to introduce this experience earlier in students' engineering education, so they have more practice using these essential skills. Smaller scale projects should be introduced in the preliminary design courses *Biosystems Engineering Design 1* and *Biosystems Engineering Design 2* to facilitate the development of these skills. These preliminary and mid-year projects should be/include Indigenous projects. This will introduce engineering students to Indigenous clients, stakeholders, and community members so that engineering students can begin to work with and learn from Indigenous Peoples.

6. Broaden the scope of capstone projects, focusing on interdisciplinary teams and collaborations with Indigenous clients, stakeholders, and communities.

Many of the clients that Biosystems Engineering students work with in the capstone course are engineers. To broaden the scope of projects offered and increase students' exposure to diverse perspectives, an interdisciplinary approach should be considered. Engineers often work with other professionals to develop solutions, and in Manitoba engineering graduates will likely work with Indigenous communities (Mante et al. 2019). This could be reflected in the capstone course if Biosystems Engineering students worked with university students outside the Price Faculty of Engineering and with Indigenous clients. For example, Biosystems Engineering students could collaborate with senior Kinesiology and Recreation Management, Native Studies, or Asper School of Business students on a project with Indigenous communities and stakeholders. This would encourage students to reflect on their engineering



Theme 3. Coalescing dominant, Indigenous, and engineering perspectives.



Theme 4. Preparing students for professional practice with Indigenous Peoples.

perspectives and enable them to understand engineering projects from different points of view, enhancing their understanding of the dominant/Western, Indigenous and engineering perspectives (Kennedy et al. 2016).

7. Develop a course to prepare students for professional practice with local Indigenous Peoples and communities.

Develop a course to prepare students for professional practice that provides a contextualized and in depth understanding of the Act, By-laws, and Code of Ethics (ABCs) for engineering professional practice in Manitoba, and essential knowledge about working with Indigenous Peoples and communities in Manitoba (or specific locale). The course should include knowledges about the Treaties in Manitoba (or locale) and Canada; best practices for consultation with Indigenous communities for engineering projects; principles for cultural competency and humility (Chavez 2012); an understanding of ethics from Indigenous perspectives; and political, cultural, historical, social, economic, and emotional competency training for developing relationships and collaborations with Indigenous Peoples and communities. This course could also be made available to engineers who are newcomers in the province.

8. Designate engineering technology and society course as mandatory so all students receive education on Indigenous Knowledges and perspectives in relation to engineering.

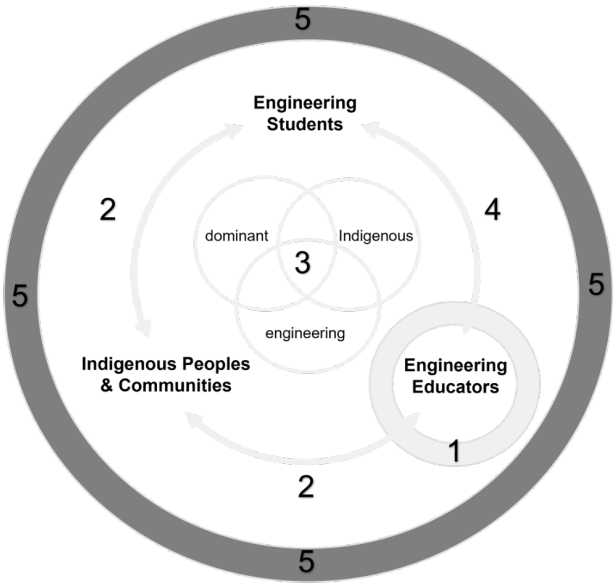
Currently, *Ecology, Technology and Society*, an Anthropology course at the University of Manitoba is accepted as an equivalent course for the engineering core course *Technology, Society, and the Future*. The Anthropology course presents an overview of the sociopolitical circumstances and effects of technology on a broad range of societies but does not offer opportunities to learn about local Indigenous Knowledges or perspectives in the specific context of engineering. To ensure all Biosystems Engineering students are informed about the impact of engineering on local Indigenous Peoples and communities, *Technology, Society, and the Future* should be mandatory for all undergraduate Biosystems Engineering students as it includes Indigenous content specific to engineering and Manitoba (Mante et al. 2019; Thomsen et al. 2021; Kilada et al. 2021).

9. Support the redevelopment of core engineering courses with Indigenous Knowledges and perspectives.

Friesen and Herrmann (2018) describe ways in which three core engineering courses offered in the Price Faculty of Engineering at the University of Manitoba can be redeveloped to include Indigenous Knowledges and perspectives and ensure students are aware of Indigenous engineering. This redevelopment should be actively encouraged and monitored by the Department of Biosystems Engineering to ensure students are receiving this education, as well as to align and not repeat curricular efforts in the program (e.g., inviting the same Indigenous guest speaker to speak on the same topic in multiple courses). These courses can also be used as models to redevelop core Department of Biosystems Engineering courses such as *Impact of Engineering on the Environment and Plant* and *Animal Physiology for Engineers* to include Indigenous Knowledges and perspectives.

10. Create new learning outcomes for engineering curricula.

New curricular learning outcomes should be created to ensure that the education of Biosystems Engineering students include Indigenous Knowledges, perspectives,



Theme 5. Develop a new curriculum.

values and cultures, and that this education is conducted in a decolonized context. These outcomes should be integrated into the CEAB graduate attributes as learning outcomes or learning indicators to ensure accountability in the department.

CONCLUSION

It is vital that all engineering students learn about Indigenous worldviews, consider Indigenous Knowledges, perspectives, values and cultures, and have collaborative experiences and build relationships with Indigenous Peoples and local Indigenous communities. Biosystems Engineering is uniquely suited to bridge Western, engineering, and Indigenous Knowledges and perspectives in the curriculum. Engineering that respects biological systems could be reflective of holistic, relational approaches shared by many Indigenous cultures. This would diversify Biosystems Engineering students' understanding of the biological world, and strengthen their ability to solve complex problems with respect for the sustainability and health of all living systems.

This rapid grey and academic literature scoping review demonstrates that there is work being done to bring Indigenous Peoples and communities, and their Knowledges, perspectives, values and cultures into engineering education in Canada, the USA, Australia, and New Zealand, but there is much work to be done. While there is not one way for decolonizing and Indigenizing engineering curricula, best practices can be shared. The 10 Calls to Action for Engineering Educators organized by the five themes that emerged from the literature should be adopted by Biosystems Engineering as well as other engineering programs. To bring forth enhanced and location-specific curricula, it is essential to build relationships and incorporate Indigenous ways of knowing, being and doing into engineering education in collaboration with local Indigenous community members. Non-Indigenous educators who deliver these new curricula must be educated to do so. Emphasizing technical education is fundamental in the engineering curriculum, but so too is social, political, historical and cultural education. Collaborating with Indigenous Peoples and communities will help in recruiting and retaining Indigenous and diverse engineering students and will critically and ethically advance engineering education in Manitoba, in Canada, and around the world.

ACKNOWLEDGEMENTS

We thank Elder Norman Meade, the Elder-in-Residence in the Price Faculty of Engineering, who shared his time and teachings with us and guided us throughout this project so that we would do this work in a good way.

We acknowledge that we are visitors on Indigenous lands where this project took place. The University of Manitoba is located on Treaty 1 traditional territory of the Anishinaabeg, Cree, Oji-Cree, Dakota, and Dene Peoples, and the homeland of the Métis Nation.

REFERENCES

Anderson, I. and S. S. Jordan. 2018. Engineering connections in a Native American community and culture. In 2018 ASEE Annual Conference and Exposition, Conference Proceedings, 2-7. Salt Lake City, UT. June 24-27.

Arksey, H. and L. O'Malley. 2005. Scoping studies: Towards a methodological framework. *International Journal of Social Research Methodology: Theory and Practice* 8: 19-32. https://doi.org/10.1080/1364557032000119616

Baillie, C. 2011. A multidisciplinary approach to curriculum development for engineering graduates who are socially and environmentally just. In 2011 ASEE Annual Conference and Exposition, Conference Proceedings, 2-11. Vacouver, BC. June 26-29.

Bang, M. and D. Medin. 2010. Cultural processes in science education: Supporting the navigation of multiple epistemologies. *Science Education* 94: 1008-1026. https://doi.org/10.1002/sce.20392

Battiste, M. 2002. Indigenous knowledge and pedagogy in First Nations education a literature review with recommendations. Ottawa, ON: Indian and Northern Affairs Canada.

Benning, J., A. Surovek, D. Dolan, L. Wilson, A. Thompson and R. Pyatt. 2015. Cultural considerations in service learning with American Indian Reservation community stakeholders. In 2015 Proceedings - Frontiers in Education Conference. Madrid, Spain, October 22-25. https://doi.org/10.1109/FIE.2014.7044323

Chavez, V. 2012. Cultural Humility: People, Principles, and Practices. YouTube. https://www.youtube.com/watch?v=SaSHLbS1V4w. (2021/05/03)

Chandna, K., M. M. Vine, S. J. Snelling, R. Harris, J. Smylie and H. Manson. 2019. Principles, approaches,

and methods for evaluation in indigenous contexts: A grey literature scoping review. *Canadian Journal of Program Evaluation* 34: 21-47.
https://doi.org/10.3138/cjpe.43050

Colston, N. M., S. L. Turner, G. M. Chagil, S. C. Jacobs and S. Johnson. 2019. Exploring the career thinking of native American engineering students. In 2019 ASEE Annual Conference and Exposition, Conference Proceedings, 1-15. Tampa, FL. June 16-19.

Corntassel, J. 2012. Re-envisioning resurgence: Indigenous pathways to decolonization and sustainable self-determination. *Decolonization: Indigeneity, Education and Society* 1(1):86-101.

Cram, F. 2016. Lessons on decolonizing evaluation from Kaupapa Māori evaluation. *Canadian Journal of Program Evaluation* 30 (3):296-312.
https://doi.org/10.3138/cjpe.30.3.04

Droz, P. E. 2014. Biocultural engineering design: An Anishinaabe analysis for building sustainable nations. *American Indian Culture and Research Journal* 38: 105-126.
https://doi.org/10.17953/aicr.38.4.w1g6521017726785

Dubiel, C., R. Greene, S. Bailey, J. Seniuk Cicek and F. Delijani, F. 2021. An adapted engineering design process: Guiding touchstones. In Proceedings 2021 Canadian Engineering Education Association (CEEA-ACEG19) Conference. University of Prince Edward Island, PEI (virtual). June 21-23 [upcoming].
https://doi.org/10.24908/pceea.vi0.14971

Ermine, W., R. Sinclair and B. Jeffery. 2004. The ethics of research involving Indigenous Peoples. Saskatoon, SK: Indigenous Peoples' Health Research Centre.

Fitz-Gerald, L. 2015. Professor explores the ingenuity of Aboriginal engineering. The Shief. https://thesheaf.com/2015/10/08/professor-explores-the-ingenuity-of-aboriginal-engineering/. (2021/01/03).

Forrest, R. and J. Seniuk Cicek. 2021. Rethinking the engineering design process: Advantages of incorporating Indigenous knowledges, perspectives, and methodologies. In Proceedings 2021 Canadian Engineering Education Association (CEEA-ACEG19) Conference. University of Prince Edward Island, PEI (virtual). June 21-23 [upcoming].

Foster, C. H. and S. S. Jordan. 2014. A philosophy of learning engineering and a native American philosophy of learning

An analysis for congruency. In 2014 ASEE Annual Conference and Exposition, Conference Proceedings. Indianapolis, IN. June 15-18.

Friesen, M. and R. Herrmann. 2018. Indigenous knowledge, perspectives, and design principles in the engineering curriculum. In Proceedings 2018 Canadian Engineering Education Association (CEEA-ACEG18) Conference, 1-10. Vancouver, BC. June 3-6.
https://doi.org/10.24908/pceea.v0i0.12964

Frey, J. B., S. Maw, S. Bens, J. Bugg and B. Sparling. 2018. Design of a Completely New First Year Engineering Program at the University of Saskatchewan - Part II. In Proceedings 2018 Canadian Engineering Education Association (CEEA-ACEG18) Conference, 1-8. Vancouver, BC. June 3-6.

Ganann, R., D. Ciliska and H. Thomas. 2010. Expediting systematic reviews: methods and implications of rapid reviews. *Implementation Science* 5: 56.
https://doi.org/10.1186/1748-5908-5-56

Gaudry, A. and D. Lorenz. 2018. Indigenization as inclusion, reconciliation, and decolonization: navigating the different visions for indigenizing the Canadian academy. *Alter Native* 14(3): 218-227.
https://doi.org/10.1177/1177180118785382

Godfrey, E. and R. King. 2010. Scoping the opportunities to aid recruitment and retention of Indigenous students in engineering. In 2010 ASEE Annual Conference and Exposition, Conference Proceedings. Lousiville, KY. June 20-23.

Goldfinch, T. and J. Kennedy. 2013. Understanding Indigenous consultation and engagement in engineering education. In Proceedings of the AAEE 2013 24th Annual Conference, 1-10. Brisbane, Qld. December 8-11.

Goldfinch, T., A. Ilango, A. Roland and J. Willis. 2014. Australian Indigenous culture and heritage in engineering project planning and the implications for engineering education. In Proceedings of the AAEE 2014 25th Annual Conference, 247-254. Wellington, New Zealand. December 8-10.

Goldfinch, T., L. Jolly, J. K. Prpic and E. Leigh. 2016a. Australian engineering educators' perceptions of indigenous cultures and challenges of minority inclusion. In 44th Annual Conference of the European Society for Engineering Education - Engineering Education on Top of the World: Industry-University Cooperation, SEFI 2016. Tampere, Finland. September 12-16.

Goldfinch, Tom, J. Kennedy, E. Leigh, L. Dawes, J. K. Prpic and T. Mccarthy. 2016b. Embedding Indigenous perspectives into engineering education. Australian Government Department of Education.

Goldfinch, T., J. Kaya Prpic, L. Jolly, E. Leigh and J. Kennedy. 2017. Australian engineering educators' attitudes towards Aboriginal cultures and perspectives. *European Journal of Engineering Education* 42: 429-444. https://doi.org/10.1080/03043797.2017.1328588

Government of Canada. (2014). Indigenous and northern affairs Canada. https://www.aadnc-aandc.gc.ca/eng/1100100020400/1100100020404. (2021/01/03).

Grommes, A. V and D. R. Riley. 2004. Learning from native cultures: educational opportunities in sustainability, cultural sensitivity and global awareness.

In 2004 ASEE Annual Conference and Exposition, Conference Proceedings. Salt Lake City, UT. June 20-23.

Grover, J. G. 2010. Challenges in applying Indigenous evaluation practices in mainstream grant programs to Indigenous communities. *Canadian Journal of Program Evaluation* 23(2):33-50.

Harrison, S., J. Simcoe, D. Smith and J. Stein. 2018. Pulling Together: A Guide for Leaders and Administrators, British Columbia: BC Campus.

Haruo Eikenaar, J. 2018. Indigenizing the applied science curriculum at UBC's school of Engineering. In Proceedings 2018 Canadian Engineering Education Association (CEEA-ACEG18) Conference, Paper 007. Vacouver, BC. June 3-6.

https://doi.org/10.24908/pceea.v0i0.12955

Herrmann, R. 2020. Indigenous technologies. University of Manitoba BIOE4950, Winnipeg, Manitoba, Canada. (2020/01/27).

Hollis, X. and T. Goldfinch. 2017. Experience, education and training on Aboriginal Cultural Heritage in engineering. *Australasian Journal of Engineering Education* 22: 54-62.

https://doi.org/10.1080/22054952.2017.1367362

Hughes, M. W., J. K. Prpic, T. Goldfinch and J. Kennedy. 2018. He Awa Whiria : Weaving Indigenous and Western perspectives and creating inclusion in Australasian engineering education. In Proceedings of the AAEE 2018 29th Annual Conference. Hamilton, Victoria. December 9-12.

Johnson, E. A. 2016. Mitigating social risk in the extractive sector: developing intercultural competence as a tool for negotiating western-Indigenous perspectives within the undergraduate mining engineering curriculum. Unpublished Ph.D. thesis. Kingston, ON: Depatrment of Mining Engineering, Queen's University.

Johnson, A. 2020. A Theoretical Basis for Addressing Culture in Undergraduate Mining Education. *International Journal of Engineering, Social Justice, and Peace* 7: 1-20.

https://doi.org/10.24908/ijesjp.v7i1.13586

Jordan, S. S., C. H. Foster, I. K. Anderson, C. A. Betoney and T. J. D. Pangan. 2019. Learning from the experiences of Navajo engineers: Looking toward the development of a culturally responsive engineering curriculum. *Journal of Engineering Education* 108: 355-376. https://doi.org/10.1002/jee.20287

Katz, M. 2020. The need for socially responsible university educated professionals in the extractive industries. *Extractive Industries and Society* 7 (4): 1351-1353.

https://doi.org/10.1016/j.exis.2020.10.015

Kennedy, J., T. Goldfinch, E. Leigh, J. Kaya Prpic, T. Mccarthy and L. Dawes. 2016. A beginner's guide to incorporating Aboriginal perspectives into engineering curricula. Australian Government Office for Learning and Teaching.

Kilada, G., V.Thomsen, J.Seniuk Cicek and A. Adobea Mante, A. 2021. Assessing the impact of the integration of Indigenous knowledges and perspectives into the engineering curriculum on students' learning. In Proceedings 2021 Canadian Engineering Education Association (CEEA-ACEG19) Conference. University of Prince Edward Island, PEI (virtual). June 21-23 [upcoming]. https://doi.org/10.24908/pceea.vi0.14909

Kimmerer, R.W. (2013). Braiding Sweetgrass: Indigenous Wisom, Scientific Knowledge, and Teachings of Plants. Minneapolis, MN: Milkweed Editions.

Kutay, C. and E. Leigh. 2017a. Aboriginal engineering for an enduring civilisation. In Proceedings of the AAEE 2017 28th Annual Conference. Sydney, NSW. December 10-13.

Kutay, C. and E.Leigh. 2017b. Validating storytelling for indigenous knowledge teaching. In Proceedings of the AAEE 2017 28th Annual Conference, 385-386. Hamilton, Victoria. December 9-12.

Latimer, J. 2020. Concordia's Kasim Ali Tirmizey is integrating Indigenous knowledge in his course curriculum.
https://www.concordia.ca/news/stories/2020/02/12/concordia-professor-kasim-ali-tirmizey-indigenizes-his-course-curriculum.html. (2021/01/03).

Ledoux, J. 2006. Integrating Aboriginal perspectives into curricula: A literature review. *The Canadian Journal of Native Studies* 26(2):265-288.

Leigh, E., T. Goldfinch, J. Kaya Prpic, L. Dawes, J. Kennedy and T. McCarthy. 2014a. Shared values: diverse perspectives - engaging engineering educators in integrating Indigenous engineering knowledge into current curricula. In Proceedings of the AAEE 2014 25th Annual Conference. Wellington, New Zealand. December 8-10.

Leigh, E., T. Goldfinch, T. Mccarthy, J. Kennedy, L. Dawes and J. Kaya. 2014b. Master class - Indigenous engineering, a pathway to reconciliation / Intercultural competence? In Proceedings of the AAEE 2014 25th Annual Conference. Wellington, New Zealand. December 8-10.

Leigh, E., L. Dawes, T. Goldfinch, J. K. Prpic, J. Kennedy and T. Mccarthy. 2015. Shifting Perspectives - Changing direction. Integrating Aboriginal Engineering into modern engineering curricula.

Levac, D., H. Colquhoun and K.K. O'Brien. 2010. Scoping studies: advancing the methodology. *Implementation Science* 5: 69. https://doi.org/10.1186/1748-5908-5-69

Leydens, J. A., T. K. K. B. Morgan and J. C. Lucena. 2017. Mechanisms by which indigenous students achieved a sense of belonging and identity in engineering education. In 2017 ASEE Annual Conference and Exposition, Conference Proceedings. Columbus, OH. June 25-28.

Lord, S. M., J. A. Mejia, G. D. Hoople and D. A. Chen. 2019. Special session: Starting a dialogue on decolonization in engineering education. In 2019 Proceedings - Frontiers in Education Conference, FIE2019. Covington, KY. October 16-19. https://doi.org/10.1109/FIE43999.2019.9028477

Mante, A. A., J. Seniuk Cicek, M. Friesen and L. Kavanagh. 2019. Assessing the impact of integrating Indigenous knowledges and perspectives in engineering curricula on student's learning: the development of a classroom case study. In Proceedings 2019 Canadian Engineering Education Association (CEEA-ACEG19) Conference, 2:17-23. Ottawa, ON. June 8-12. https://doi.org/10.24908/pceea.vi0.13881

Matusovich, H.M., M.C. Paretti, L.D. McNair and C. Hixson. 2014. Faculty motivation: A gateway to transforming engineering education. *Journal of Engineering Education.* 103(2): 302-330. https://doi.org/10.1002/jee.20044

Mehta, Y., P. M. Jansson and D. Dorland. 2007. Learning through the design of a fish hatchery for a community on the Cheyenne river reservation - An EWB service-learning project. In 2007 ASEE Annual Conference and Exposition, Conference Proceedings. Honolulu, HI. June 24-27.

Mejia, J. A. and M. N. De Paula. 2019. " Ingeniero como vos ": An analysis of the Mbya-Guarani practices associated with engineering design. In 2019 ASEE Annual Conference and Exposition, Conference Proceedings. Tampa, FL. June 16-19.

Momo, B., G. D. Hoople, D. A. Chen, J. A. Mejia and S. M. Lord. 2020. Broadening the Engineering Canon: How Culturally Responsive Pedagogies Can Help Educate the Engineers of the Future. *Murmurations* 2 (1): 6-21. https://doi.org/10.31946/meee.v2i1.32

Murray, M. R. and T. K. K. B. Morgan. 2009. An indigenous approach to engineering effective learning opportunities.In Proceedings of the AAEE 2009 20th Annual Conference. Adelaide, SA. December 6-9.

Murray, J. K., J.A. Studer, S.R. Daly, S. McKilligan and C.M. Seifert S. 2019. Design by taking perspectives: how engineers explore problems. *Journal of Engineering Education* 108(2): 248-275. https://doi.org/10.1002/jee.20263

O'Sullivan, A. and T. Cochrane. 2009. Preparing better engineers: Compulsory undergraduate research projects that benefit universities and the profession. In 2009 ASEE Annual Conference and Exposition, Conference Proceedings. Austin, TX. June 14-17.

O'Sullivan, N. 2019. Walking backwards into the future: Indigenous wisdom within design education. *Educational Philosophy and Theory* 51: 424-433. https://doi.org/10.1080/00131857.2018.1476236

Ouzzani, M., H. Hossam, Z. Fedorowicz and A. Elmagarmid. 2016. Rayyan - a web and mobile app for systematic reviews. *Systematic Reviews* 5:210. https://doi.org/10.1186/s13643-016-0384-4

Partridge, C. 2010. Residential schools: the intergenerational impacts on Aboriginal Peoples. *Native Social Work Journal* 7: 33-62.

Prpic, J. K. and D. Bell. 2018. Designing an on-country engineering education experience in collaboration with the Gunditjmara community. In Proceedings of the AAEE 2018 29th Annual Conference. Hamilton, New Zealand. December 9-12.

Reconciling Ways of Knowing: Indigenous Knowledge and Science Forum. 2020. Dialogue 1: Why Reconciling Ways of Knowing? . https://www.waysofknowingforum.ca/. (2021/01/03)

Rhamdhani, M. A., K. Salehi, Y. C. Wong, A. Kapoor and A. Vakhguelt. 2009. How are engineering graduates prepared to work in a culturally changing world? Current practices. In Proceedings of the AAEE 2009 20th Annual Conference. Adelaide, SA. December 6-12.

Riley, D. R., C. E. Thatcher and E. A. Workman. 2006. Developing and applying green building technology in an indigenous community: An engaged approach to sustainability education. *International Journal of Sustainability in Higher Education* 7: 142-157. https://doi.org/10.1108/14676370610655922

Roberto, P., S. Pellucci, R. R. De Paula, W. B. De Oliveira and A. P. Ladeira. 2020. Use of an Indigenous learning bundle in an engineering project course. In Proceedings 2020 Canadian Engineering Education Association (CEEA-ACEG20) Conference, 89:73-81. Montreal, QC. June 18-21.

Seniuk Cicek, J., A. Mante, C. Geddert and L. Fontaine. 2019a. Engineering education re-interpreted using the indigenous sacred hoop framework. In Research in Engineering Education Symposium: Making Connections. Cape Town, South Africa. July 10-12.

Seniuk Cicek, J., M. Friesen and S. Bailey. 2019b. Transdisciplinary design build studio course in collaboration with Shoal Lake 40 First Nation: Development and assessment. In 2019 Proceedings - Frontiers in Education Conference, FIE 2019. Covington, KY. October 16-19. https://doi.org/10.1109/FIE43999.2019.9028515

Seniuk Cicek, J., A. Mante, M. Friesen and R. Herrmann. 2019c. Enhancing engineering Education with Indigenous Cultures, Pedagogies, Knowledges and Perepectives: A Series of Faculy Workshops. In Proceedings 2019 Canadian Engineering Education Association (CEEA-ACEG19) Conference, 1-6. Ottawa, ON. June 8-12. https://doi.org/10.24908/pceea.vi0.13835

Seniuk Cicek, J., A.L. Burgart, D. Rogalski, S. Gauthier, S. Mattucci, J. Bazylak, A. Mante, M Robinson, R. Herrmann and S. Staub-French. 2020. Indigenous initiatives in engineering education in Canada: Collective contributions. In Proceedings 2020 Canadian Engineering Education Association (CEEA-ACEG20) Conference. Montreal, QC. June 18-21. https://doi.org/10.24908/pceea.vi0.14162

Sprowles, A., K. Goldenberg, S. Ladwig and F. Shaughnessy. 2019. Place-based learning communities on a rural campus: Turning challenges into assets. *Learning Communities Research and Practice* 7: 6.

Statistics Canada. 2017. Focus on Geography Series, 2016 Census. https://www12.statcan.gc.ca/census-recensement/2016/as-sa/fogs-spg/Facts-PR-Eng.cfm?TOPIC=9&LANG=Eng&GK=PR&GC=46(2021/04/14).

Steele, A. L., C. Schramm, and K. Horn-Miller. 2020. Use of an Indigenous learning bundle in an engineering project course. In Proceedings 2020 Canadian Engineering Education Association (CEEA-ACEG20) Conference. Montreal, QC. June 18-21. https://doi.org/10.24908/pceea.vi0.14138

Thomsen, V., J. Seniuk Cicek and A. Adobea Mante. 2021. Integrating Indigenous knowledges in engineering curricula: A student perspective." In Proceedings 2021 Canadian Engineering Education Association (CEEA-ACEG21) Conference. University of Prince Edward Island, PEI (virtual). June 21-23 [upcoming].

TRC. 2015. Truth and reconciliation commission of Canada: Calls to action. Winnipeg, MB: Truth and Reconcilliation Comission of Canada.

University of British Columbia. 2020. Truth and the role of engineers in decolonization. https://apsc.ubc.ca/event/2020/truth-and-role-of-engineers-decolonization. (2021/01/03).

University of Manitoba. (2020a). Facts and figures Indigenous achievement. https://umanitoba.ca/about/factandfigures/#academic-units. (2021/01/03).

University of Manitoba. (2020b). Reconcilliation. https://umanitoba.ca/indigenous/reconciliation. (2021/01/03).

University of Manitoba. (2020c). Student Advising Assistance. umanitoba.ca/faculties/engineering/departments/biosystems/undergrad/biosystemsstudentadvisingassistance.html. (2021/01/03).

Vowel, C. 2017. Indigenization in the time of pipelines. 2016-2017. Weweni Indigenous scholars speaker series. University of Winnipeg. https://www.youtube.com/watch?v=_h8ucu3J-tk&feature=youtu.be. (2021/01/03).

Wiseman, D. and R. Herrmann. 2018. Good, now keep going: challenging the status quo in STEM pipeline and access programs. *Cultural Studies of Science Education* 14: 129-137. https://doi.org/10.1007/s11422-018-9863-3

Wong, C., K. Ballegooyen, L. Ignace, M. Jane, G. Johnson, and H. Swanson. 2020. Towards reconciliation: 10 Calls to Action to natural scientists working in Canada. *Facets*: 769-783. https://doi.org/10.1139/facets-2020-0005