Consultant Report
Securing Australia's Future
STEM: Country Comparisons

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Science, Technology, Engineering and Mathematics Education and Related Employment for Indigenous Students and Citizens of Saskatchewan

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Introduction

Concern over shortages in STEM[1] skills amongst a country's potential work force typically arises when companies try to hire specifically trained men and women for knowledge-based, resource-based, and industrial employment. This context of hiring highlights the STEM capacities of post-secondary graduates, and thus it emphasizes the role of post-secondary institutions. This emphasis causes people to approach the problem in a reductionist-like way that encourages patch-work solutions – How can we increase the uptake of mature students into STEM programs at post-secondary institutions? But an alternative way to understand the problem of shortages in STEM capabilities is a more systems-like approach.

Although the patch-work approach is practical in the short term, it ignores the reality from which human resources emerge; that is, the *holistic* complex of family, social, cultural, educational, economic, and political contexts that impinge upon the personal stories of people who develop high quality STEM capabilities and values. A holistic view (a systems-like approach) recognizes the crucial roles of, for instance, early childhood education and education from Grade 1 to high school graduation, in addition to recognizing the roles of post-secondary institutions and the job training conducted by commercial and public enterprises that hire STEM-related graduates. A holist view can also reveal discrepancies between one part of the system and another; for example, on the one hand, the preoccupation of academic school programs with what abstract conceptual content should be placed in their mathematics and science curricula, and on the other, expectations of STEM employers who are not concerned with what specific content has been taught as long as an employee has the capacity to learn new STEM content on the job and be able to function smoothly with mathematics required by the job.

Accordingly, this report begins by describing a series of contexts; broadly North American ('Turtle Island' from an Indigenous[2] perspective), mostly Canadian, but focused on the province of Saskatchewan. These contexts will suggest specific frameworks and will harbour implications for answering the following questions:

1. In what ways have some Saskatchewan institutions addressed the issue of increasing STEM capacity among Indigenous citizens?
2. What solutions hold promise for future success? and What is the supporting evidence?
3. Which solutions are seen as culturally appropriate?

The report continues by composing answers according to the following major topics: school science, school mathematics, research into Indigenous students' university experiences, STEM-related technical or professional institutes/colleges, university STEM-related programs and projects, and access to STEM-related employment.

This report offers an informative *overview* of STEM education and employment opportunities for Indigenous students and Indigenous citizens of Saskatchewan; the report should not be mistaken as an exhaustive study.

[1] The acronym STEM, well known in science education circles, stands for science, technology, engineering, and mathematics.
[2] The word 'Indigenous' is used in this report to encompass worldwide the original inhabitants of a place and their descendants who have suffered colonization. A uniquely Canadian meaning is clarified just below in the subsection 'Demographic Context.'

Contexts

Demographic context

Across Canada, about 1.26 million Indigenous peoples (called 'Aboriginal' peoples by the federal government) self-identified in the 2006 census. This total was comprised of: 785,000 First Nations, 425,000 Métis, and 50,000 Inuit citizens (Richards & Scott, 2009, p. 5). The total represents 3.8% of Canada's population of about 33 million. Six of the 10 Canadian provinces account for 90% of Canada's Indigenous population: Quebec, Ontario, Manitoba, Saskatchewan, Alberta, and British Columbia (Richards & Scott, 2009, p. 42).

Depending on the locality in Canada, between one-third to one-half of First Nations people currently live on reserves, where all were at one time forcibly sequestered. The Métis and Inuit Nations do not live on reserves. Most Inuit live throughout Canada's three sparsely populated northern territories. These territories have a very large proportion on Indigenous peoples due to the territories' small total population.

As shown in Table 1 (below), the province of Saskatchewan in 2006 (population almost 1 million) had the second-highest *proportion* of First Nations and Métis citizens in Canada (14.9%) and the highest proportion of school aged children (26.1%) (Richards & Scott, 2009, p. 6). Many First Nations and Métis citizens in Saskatchewan are under the age of 25, making its school population and potential post-secondary population of Indigenous students over 26 % of its total population (Saskatchewan Ministry of Education, 2011). The proportion of Indigenous people in Saskatchewan is expected to rise from 15% to 33% by 2045 (Cooper, 2012).

Table 1. Indigenous Percentage Demographics in Selected Provinces for 2006

Province	% Ages 0-4	% Ages 5-14	% All ages	Total Population
Manitoba	27.6	25.1	15.5	1,200,000
Saskatchewan	29.0	26.1	14.9	990,000
Alberta	9.0	9.4	5.8	3,300,000
BC	8.0	8.2	4.8	4,100,000
all of Canada	6.4	6.2	3.8	33,000,000

Based on Richards & Scott, 2009, p. 6.

Canada's three 'Prairie Provinces' (Manitoba, Saskatchewan, and Alberta) have similar geographic regions; a prairie landscape in the southern part of each province and a rugged rock and lake terrain in the northern part covered entirely with coniferous and broadleaf forests. Most of Saskatchewan's population lives in its southern region, located between the 49^{th} and 54^{th} parallels of latitude where all the cities are located and where agriculture ('the bread basket of the world') and potash mining drive the economy, by and large.

Between the 54^{th} and 60^{th} parallels, a very sparse population lives in isolated towns, villages, and Indigenous reserves. Mining, forestry, and tourism drive the northern economy, but economic and social indicators paint a rather bleak picture of life in the north, although it is culturally rich and vibrant. Indigenous people make up 85% of northern Saskatchewan's population, and these people represent 21% of Saskatchewan's Indigenous population.

Political climate/context

From the 16th into the 20th century, colonization devalued, and at times destroyed, Indigenous peoples' culture and wellbeing. Promises were made through treaties signed between many of the First Nations and the British Crown on behalf of the Canadian Nation; and treaty-based promises have since been broken by the federal government. The Métis Nation was dispersed and ignored.

Today's pervasive distrust of schools by Indigenous communities is directly related to repeated actions by governments over these centuries. An evidence-based Indigenous (Native) perspective on these actions is given voice here:

> Extermination dominated the early contact period, assimilation the latter, until finally, in the nineteenth century, they came together in an amalgam of militarism and social theory that allowed North America to mount a series of benevolent assaults on Native people, assaults facilitated by force of arms, deception, and coercion, assaults that sought to dismantle Native culture with missionary zeal and humanitarian paternalism, and to replace it with something that Whites could recognize. (King, 2012, p. 102)

For example, in response to a government-initiated study in 1910 that reported a 30 to 50% mortality rate for children enrolled in western Canadian Indigenous residential schools, the Superintendent of Ottawa's Department of Indian Affairs, Duncan Scott, dismissed these data thusly: 'This alone does not justify a change in the policy of this Department, which is geared towards *the final solution of our Indian Problem*' (quoted in King, 2012, p. 114, emphasis added). A few years later Duncan stated:

> I want to get rid of the Indian problem. Our objective is to continue until there is not a single Indian in Canada that has not been absorbed into the body politic and there is no Indian question, and no Indian Department. (King, 2012, p. 72)

The purpose of residential schools, expressed in the vernacular of the time, was to 'kill the Indian and save the child.'

This national policy of cultural genocide had established Indigenous residential schools administered by religious missionary groups, which resulted in catastrophic intergenerational disruptions in parenting capabilities, self-worth, cultural self-identity, and the use of Indigenous languages; the direct legacy of which is a disproportionate frequency of dysfunctional families, chronic poverty, family violence, loss of mother tongues, social disengagement, youth suicide, criminal incarceration, and learned helplessness; all of which are barriers to educational access and success (Doctor, 2012; Richards & Scott, 2009). In Saskatchewan, the last residential school closed in 1972.

Michelle Hogue of Métis ancestry articulates the challenges faced by educators, employers, and Indigenous communities when they try to provide an education or job training that enables Indigenous people to succeed in Euro-Canadian society without losing their cultural self-identities.

> For Aboriginal people, particularly many of the Residential School survivors, education is still seen as a colonizer, and participating in Western ways-of-knowing is at the risk of losing Aboriginal ways-of-knowing. The loss of choice, voice and rights, the historical repercussions of participating [involuntarily] in Western education is still a dark cloud of concern. (Hogue, 2011, p. 293)

The political climate is also characterized by the Canadian Indian Act, which created, and continues to create, a culture of dependency by preventing or hampering First Nations peoples from developing economically and politically. For example, Warick (2012c) reported:

> For decades, First Nations people were prohibited from working off-reserve, could not sell their crops without permission of the Indian agent and faced countless other barriers. And until recently, a First Nation wanting to partner with an outside business could wait three years for federal approval. 'Who would wait that long? They walked away,' Dakota First Nations Chief Darcy Bear said.

Certainly some Indigenous Canadians have risen above this history or have healed from its legacy, as evidenced by the achievements of Indigenous people and communities described throughout this report.

Along with the Indian Act, racism is an issue – personal, systemic, and institutional racism. For instance, Canada's justice system tries to offset officially recognized discrimination against Indigenous people in sentencing decisions that had been more severe for Indigenous than for non-Indigenous offenders. In 1999, the Supreme Court of Canada cited factors such as bias, systemic racism, high unemployment, and community dislocation, which the Court identified as contributing to the 'grossly disproportionate' incarceration of Indigenous people. Judges in Canada now apply this 'Gladue Principle' that recognizes mitigating factors for Indigenous offenders when sentencing them or when ruling on a person's extradition to the United States where Indigenous heritage is not considered as it is in Canada.

An Alberta Government (2010) committee on Indigenous employment and economic development wrote: 'Throughout this [fact gathering] process, we asked everyone to share their experience, knowledge or comments about barriers and challenges to education and employment for First Nations, Métis and Inuit people in Alberta' (p. 16). The committee reached the following conclusion:

> One of the more pervasive barriers we heard about was racism, discrimination and negative stereotypes. We heard examples of discrimination against Aboriginal people by landlords, employers, individuals within government, industry, service and educational providers, human resources departments, and by citizens. Racism against Aboriginal people happens on a daily basis in schools, workplaces, and communities and it needs to be addressed. Discrimination and negative stereotypes are damaging to individuals and to communities. (p. 17)

For many Indigenous students, getting a high school diploma is not a motivation to succeed academically when

> the majority of Aboriginal students in school are hardly able to find and hold paying jobs, for reasons such as racial discrimination and the perception among them that they do not have the skills necessary to get a job or that few employers hire Aboriginal people. (Kanu, 2011, p. 127)

Beyond the positive and supportive influences of some teachers, schools, and professors lie negative influences that arise from political, economic, and social aspects of Canadian society. They cause STEM classes in schools and universities from being psychologically safe and inviting to Indigenous students.

These negative influences in Canadian society create barriers for enrolment and achievement in school and post-secondary STEM programs for Indigenous students (Richards & Scott, 2009), and obviously create negative experiences for Indigenous STEM graduates in Canadian labour markets. One crucial contributing factor is the conventional *privilege* enjoyed by Eurocentric education systems and post-secondary institutions. The status quo has historically had the power to marginalize or reject perspectives and worldviews that appeared to question its privileged status and universal legitimacy in schools and post-secondary institutions. Kanu's (2011) research in Manitoba addressed this issue:

> Despite racially and culturally diverse school demographics, many public schools in Canada still welcome multiculturalism only to the extent that it fits into, rather than challenges or disrupts, Eurocentric epistemologies [ways of thinking] and pedagogies. (p. 130)

Kanu's research into teachers' integrating Indigenous perspectives into Grade 9 social studies classes (history and social sciences) recorded what participating teachers said they faced: 'racist, stereotypical images of Aboriginal peoples held by some of their non-Aboriginal colleagues and students [is] a most difficult challenge' (p. 185). This negativity is thought to cause some Indigenous students to resist being identified as Indigenous. One teacher mentioned, 'Aboriginal students are the only cultural group in my classes who hide their identity' (p. 169). Culturally responsive teaching strategies were used by these social studies teachers to help such students feel comfortable and safe enough to self identify.

Poverty, more than any other single factor, is a barrier to student achievement. A leading cause of poverty in Indigenous families includes the political climate of Euro-Canadian privilege, racism, and intergenerational economic oppression. Poverty significantly contributes to chronic absenteeism in schools, as does the transient life of students divided between their reserves and an urban centre (Kanu, 2011).

In the political context of Canada, education and labour/employment are provincial responsibilities, not federal responsibilities; and provinces guard these responsibilities closely. Each province develops its own science curriculum. First Nations people who live off their reserves attend provincial schools, as do all Métis children.

It is important to note, however, that First Nations people who live on reserves are the responsibility of the *federal* government, including their on-reserve education. Reserves are administered by the federal government's department of Aboriginal Affairs and Northern Development Canada, under the authority of the Indian Act. Approximately one half of Saskatchewan First Nations students live on reserves, which are run by a local administrative unit 'the Band Office,' headed by an elected Chief.

In Saskatchewan, many of these Indigenous students attend reserve schools entirely funded by the federal government (an estimated 16,000 students today; Cuthand, 2012a). The school funding source – provincial or federal – creates a dramatic inequity gap. About $10,000 per student is spent in Saskatchewan provincial schools, but only $6,400 per student in First Nations federal reserve schools (Cuthand, 2012a). By comparison, $18,000 per student is spent on provincial French immersion schools, funded jointly by Saskatchewan and federal governments. (These figures refer to yearly operating costs, not to school construction and renovations.) Moreover, the federal government placed a 2% cap on funding increases several decades ago, a figure consistently below Canada's inflation rate. The inequity problem has being getting *worse* over time, especially in light of the fact that the population on most reserves has increased dramatically over those years. Thus, reserves have actually needed *greater* educational resources due to both inflation and population increases.

Indigenous education in many provinces is a treaty right. However, Band officials quickly reach their spending limits. This means, for example, that a university Indigenous student in engineering can have her funding terminated after two or three successful years of a four-year program because the reserve's money for post-secondary education is exhausted. The student is left with no financial support and drops out of engineering. On many reserves, summer jobs are almost non-existent.

Both provincial and reserve schools follow the same provincial science curriculum. The *quality* of First Nations students' experience with that curriculum on reserves, however, depends on the Aboriginal Affairs and Northern Development Canada's funding formula. As a result, students attending off-reserve schools significantly outperform their counterparts attending on-reserve schools on measures such as the level of education attained (Richards & Scott, 2009, pp. 14-15) and the level of science and mathematics achievement (Saskatchewan Ministry of Education, 2011). The quality of STEM education is undermined when, for example, reserves do not have equitable funding for early childhood programs, for up-to-date mathematics and science resources and laboratories, and for teacher salaries. Teachers earn about $5,000 less per year compared with provincial schools. A much higher rate of teacher turnover exacerbates the problem.

Inequitable funding is a major root-cause among other causes (discussed below in the section 'School Science') for on-reserve students' generally not meeting post-secondary institutions' mathematics and science competency expectations achieved by their non-Indigenous counterparts who benefit from provincial or French immersion school funding. This funding inequity creates a major barrier for most students. It is not about a lack of ability, as evidenced by on-reserve Indigenous students who have had a strong vision of participating in a STEM-related career and who have had the determination, resiliency, tenacity, and mentorship to succeed in spite of such barriers (Hogue, 2011).

On a promising positive note, a 'Joint Task Force on First Nations and Métis Education and Employment' was established in Saskatchewan in 2011; a collaboration among the Provincial Government (Ministry of Advanced Education, Employment and Immigration), the First Nations provincial political organization (the Federation of Saskatchewan Indian Nations – FSIN), and the Métis Nation political group (Métis Nation-Saskatchewan). The goal is to increase First Nations and Métis peoples' participation and success in advanced education and the labour force. Particular attention will be given to STEM education. As a result of preliminary consultations with individuals, communities, and industries, the Chair of the Task Force was reported to say (Lagimodiere, 2012):

> One of the first roadblocks that we always hear about is lack of funding,' said [former Chief] Merasty. 'The inadequate funding on-reserve and the fact that it is year-to-year and proposal driven makes it very difficult to budget. We also heard about funding issues off-reserve too, so it is really across the board. (p. 6)

In 2008, Canada's Prime Minister apologized in Parliament to Indigenous peoples for the oppressive treatment many suffered in residential schools and for its lingering intergenerational consequences today. Educators and Indigenous communities are now diligently working on healing and reconciliation. No one from the federal government, however, has yet apologized for the continuing neo-colonial[3] funding formula used by Aboriginal Affairs and Northern Development Canada.

Economic context

The under-representation of Indigenous people in STEM fields results in both economic and social disadvantages for Indigenous individuals and communities (Royal Commission on Aboriginal Peoples, 1996). The educational success of Indigenous students in STEM will have direct consequences for the economic wellbeing of Saskatchewan and Canada. Better educational attainment leads to increases in Indigenous people's earning power, increases in government tax revenue, and decreases in government program expenditures (Sharpe & Arsenault, 2009). Statistics Canada (2008) reported that Canada's Indigenous population surged past the one million mark for the first time on a national census. This figure represented a spike of 45% from a decade earlier. Newspapers across Canada published articles and editorials devoted to the consequences of this increase. For example, an editorial written by Saskatchewan's *Saskatoon StarPhoenix* (2008) stated,

> Those who argue that the status quo of forcing the Aboriginals to adapt to the existing [education] system will work, are merely burying their heads in the sand and damaging the economy, as were those in the past who argued the way to educate the Natives was to destroy their culture.

Thus, there is a general agreement in Canada over the relevance of STEM to economic growth and wellbeing (Cooper, 2012; Saskatchewan Ministry of Advanced Education, Employment and Labour, 2010).

A major Canadian economic study was conducted by Sharpe and Arsenault (2009). They wrote:

> The potential contribution of the Aboriginal population is examined under different scenarios, based on three assumptions: the educational level of Aboriginal Canadians remains unchanged over the period [2001-2026]; the educational level of Aboriginal Canadians in 2026 reaches the mid-point between its level in 2001 and that of non-Aboriginals in 2001; and Aboriginal Canadians in 2026 acquire the same

[3] Neo-colonialism is a process that systemically undermines the cultural values of a formerly colonized group.

> educational profile as that of non-Aboriginal Canadians in 2001. It is important to note that the potential dynamic effects (e.g. leadership in the community, intergenerational effects on child development) are not taken into account. In that sense, these estimates represent a lower-bound estimate of the effect of education on Aboriginal people and on Canada as a whole. (p. 17)

For the period 2001 to 2026, if the educational attainment *difference* between Indigenous and non-Indigenous were halved, the economic consequence would be an additional $7.0 to $8.2 million added to Canada's GDP in 2026, depending on labour market outcome gaps between Indigenous and non-Indigenous earners. If differences in education attainment were completely eliminated, Canada would gain an additional $16.4 million in 2026 with no decrease in labour market outcome gaps; or an additional $36.5 million in 2026 in the best case scenario in which both education attainment and labour market gaps were closed.

Thus, unemployment figures between Indigenous and non-Indigenous Canadians become crucial, especially today when Saskatchewan is recruiting international employees skilled in STEM-related occupations while the potential growth in its Indigenous workforce is not being sufficiently achieved. In Saskatchewan, total unemployment is currently at 5.2%. Among the Métis Nation, 9.4% are actively looking for work, while the figure increases to 21.3% for First Nations workers. These figures do not include people who have given up looking. There is a sizable employment gap in the labour market between Indigenous and non-Indigenous workers.

University of Saskatchewan law professor Daum-Shanks (2012) counselled:

> To make Indigenous people a part of what is making Saskatchewan prosper, we must provide the kind of means that have led others to prosperity. Would any non-Indigenous parent truly wish their child could trade places with an Indigenous kid?

From Calgary, Alberta, Mount Royal University professor Doctor (2012) wrote:

> The long-term social and economic success of Canada is intrinsically tied to our Aboriginal Peoples, and the success of Aboriginal Peoples requires addressing both social and economic issues. At the cornerstone of both social and economic success is education.

Many Indigenous families and all Indigenous communities place high value on education as a solution to poverty. Education – 'the new buffalo' – is seen as a major contributor to economic progress (Stonechild, 2006). The expression refers back to the days when the buffalo (a.k.a. bison) roamed the North American prairie and provided the main source of food, clothing, and shelter. Several First Nations in Saskatchewan have illustrated what can happen when the results of post-secondary education are put into practice for the betterment of the reserve. Three examples illustrate the emerging power of the new buffalo.

The first example is Onion Lake Cree Nation. Chief Walking Bear once asked, 'How do we move our families forward into education, training, careers and success?' (Warick, 2012a) When oil was discovered on their reserve in the 1970s, the Elders and leaders realized their people 'did not possess the necessary expertise or skills to negotiate a fair deal or supply workers. A moratorium was placed on exploration' (Warick, 2012a), and a great deal of attention was given to the new buffalo. When the moratorium was lifted several years ago, Onion Lake's economy flourished through partnerships with businesses to extract the oil, and as a result, the employment of Onion Lake workers increased. Their First Nations development corporation expects to receive $80 million in total revenue this year.

The effects of the new buffalo are illustrated by the Whitecap Dakota Nation. Over the past decade, they created a world-class golf course accompanied by a casino. The reserve has prospered through wise decisions, dedicated education, and plain hard work. Currently, a new hotel and convention centre are under construction. The hotel alone will bring in more jobs than Whitecap's population. Chief Darcy Bear exclaimed, 'There's no better role modelling than seeing mom and dad go to work' (Warick, 2012c).

The last example concerns a $150 million bioenergy centre currently under development by the Meadow Lake Tribal Council, a political confederation of nine First Nations that straddle the north and south regions of Saskatchewan. 'It is one of the most ambitious green energy projects in Saskatchewan's history. Wood waste will be converted into energy, powering an estimated 30,000 homes' (Warick, 2012b). The emphasis placed on green energy reflects a fundamental Indigenous understanding about their balanced relationship with Mother Earth. In English it is called sustainability. A translation from Indigenous languages would likely be 'living properly.' Indigenous ways of knowing nature combine the ontology (assumptions about reality) of monism and spirituality, with the epistemology (ways of knowing) of place-based, holistic, relational, and empirical practices, in order to celebrate an ideology of harmony with nature for the purpose of community survival.

A strong impetus behind some of these successes is the Treaty Land Entitlement Agreement signed in 1992 by the Federation of Saskatchewan Indian Nations (FSIN – the province's First Nations political organization), the federal government, and the provincial government. The signing came after years of lobbying and negotiating, all aimed at rectifying the federal government's broken promises following the original treaties signed in the 1870s. The 1992 agreement set aside money for First Nations Bands to purchase land they never received but were entitled to receive. With this money Bands have begun to purchase land of historical significance, agriculture property, and urban properties ('urban reserves'). The process, however, continues at an atrociously slow pace and with constant frustrations for First Nations Bands. Nevertheless, 'Today Treaty Land Entitlement is one of the building blocks of economic development and cultural revival' (Cuthand, 2012b). As described near the end of the next subsection ('Cultural and Linguistic Contexts') and in the Conclusion to the section 'School Science,' there is a causal link between (a) a community's cultural revival expressed by the strength of an Indigenous student's cultural identity, and (b) that student's academic achievement in all subjects, including STEM. But success does not automatically arise by engaging in education alone. Students will only succeed in making contributions to their communities and to Canada when 'they learn how to be leaders, how to believe in themselves and to take care of themselves and their families (Doctor, 2012).

Cultural and linguistic contexts

The word 'education' has widely different meanings for Indigenous and Euro-Canadian cultures. From an Indigenous point of view, 'An inter-relatedness, inter-connection, attentiveness to all domains, respect for both Mother Earth and the spiritual are intertwined deeply with learning or what we call education' (Hogue, 2011, p. 290). These Indigenous expectations of education make Euro-Canadian public education look inadequate in the eyes of Indigenous peoples. The two cultures have different ways of knowing, but there is also wide variation in ways of knowing within each culture – Indigenous and Euro-Canadian cultures. Stereotyping, therefore, is to be avoided.

STEM epistemology (ways of knowing) operates on quite different presuppositions than Indigenous epistemology, but they share some common attributes and values (Aikenhead & Michell, 2011). For instance, both are anchored in culture: Euro-American culture for STEM. Students of any culture can join one of STEM's subcultures or paradigms, but they first must be accepted into that subculture or community of scientists or engineers; that is, they must learn how to survive and prosper within that subculture. That is what university post-graduate programs are for. They are enculturation programs into *the culture of STEM*. Similarly, undergraduate STEM programs act as gate-keepers to 'weed out' those who do not 'pass muster'; to use the language of that subculture. To be clear, STEM Ph.D. programs are supposed to teach *Eurocentric* sciences, which are a professional repository of specialized understandings and skills to meet the competency expectations of employers of STEM graduates. In the purview of Indigenous students' experiences, however, it becomes paramount for policy makers to understand STEM as being anchored in a culture and in a set of worldviews far more similar to Euro-American cultures and worldviews than to Indigenous cultures and worldviews.

Blackfoot Elder Leroy Little Bear (2012) of Alberta, who formerly headed Harvard University's Native American Program, said that European languages were insufficient for quantum physicists to accurately describe the natural world. 'They had to resort to the invention of mathematics to describe what's going on.' But in Indigenous languages 'there is little reference to numbers because the language is so rich we don't have to resort to mathematics to describe what's going on'. The beauty and power of Indigenous languages offer unique windows into understanding the natural world, different from the windows opened by the beauty and power of mathematics. Elder Little Bear sheds light on the cultural aspects of both Indigenous and STEM perspectives. He is not at all suggesting that an Indigenous perspective replace a STEM perspective. Instead, he is saying that both perspectives are powerful and complementary ways of understanding the natural world.

Another paramount understanding for policy makers concerns what gets lost in translation between English and Indigenous languages. When Indigenous language speakers express themselves in English, they are often unable to convey exactly what they mean – a meaning originally constructed in their own language. For example, Aikenhead and Michell (2011) analyzed this problem using the English phrase 'Indigenous knowledge'.

> The noun 'knowledge' does not translate easily into most Indigenous languages, in part because English is a noun-rich linguistic system while Indigenous languages are verb-rich. When translated into English, the corresponding Indigenous expression for 'knowledge' often results in something like 'ways of living' or 'ways of being.' Thus, it is appropriate to adopt the more authentic phrase 'ways of living in nature' in place of 'knowledge of nature.' The phrase 'scientific knowledge' fits the context of Eurocentric thinking, whereas the expression 'ways of living in nature'

> generally fits an Indigenous context, although different communities may prefer different wording. (p. 65)

Because the expression 'Indigenous ways of living in nature' is not generally well known, this report will continue to use the conventional expression 'Indigenous knowledge,' but the reader is encouraged to substitute the more authentic and decolonizing expression as seen from an Indigenous perspective, rather than forcing Indigenous people into thinking in terms of the Anglo word 'knowledge'.

A Ph.D. mathematics professor of Mohawk ancestry happened to have learned his Mohawk language in his late teens (Hogue, 2011). He said, 'For one thing I tried to learn [it] not only for my own good but it does one considerable good to learn an Aboriginal language because it gives you a whole different perspective. *That is really where the culture is held, inside the language*' (p. 139, emphasis added). Research in Saskatchewan schools confirms this (Michell, 2008).

Aikenhead and Elliott (2010) summarized some of the cultural aspects of Indigenous and STEM perspectives this way:

> Although Indigenous and scientific knowledge systems share some fundamental features (e.g., both are culture-based, empirical, experimental, rational, communal, and dynamic), and although both embrace common values (e.g., honesty, perseverance, open-mindedness, curiosity, aesthetic beauty, repeatability, and precision), their worldviews tend to be ontologically, epistemologically, and axiologically incommensurate. (p. 326)

Metaphorically, scientists or engineers *see* or *design* the physical world, while Indigenous Elders *inhabit* the physical-metaphysical world.

When we combine scientific and Indigenous knowledge in school science as we do in Saskatchewan, we are presenting students with two cultural knowledge systems:

- a scientific system based on an intellectual tradition of thinking, and
- an Indigenous system based on a wisdom tradition of thinking, living, and being.

The two coexist; they are not in competition with each other. *All* students are expected *to understand* the best of both ways of knowing nature. But students are not necessarily expected *to believe* what they understand. Their beliefs are personal. It is expected that Indigenous students will come to understand the curriculum's scientific content, processes, and values while at the same time strengthening their own cultural self-identities, rather than hiding, rejecting, or replacing them with a Eurocentric identity. Stronger cultural self-identities invariably cause an overall increase in Indigenous students' academic achievement (Aikenhead & Michell, 2011; Barnhardt, Kawagley, & Hill, 2000; Brayboy & Castagno, 2008; Richards, Hove, & Afolabi, 2008).

Due to their Indigenous cultures and languages, Indigenous students fundamentally experience the world somewhat differently than Canadian mainstream students who have been raised within a Euro-Canadian milieu. STEM programs and employment resonate with this Euro-Canadian milieu. As a consequence, Indigenous students face far greater culture-clash types of challenges than most mainstream students when engaging with STEM content and skills in school science and mathematics and in post-secondary STEM programs. Indigenous students must work through culture clashes unknown to many non-Indigenous students and unknown to their STEM teachers and professors. As a result, Indigenous students have become marginalized in these school subjects and STEM programs, and as adults, do not currently participate equitably in the many STEM occupations that offer economic wellbeing.

A crucial policy statement is now gaining traction in Saskatchewan's science and mathematics curricula: *Indigenous students should not have to set aside or devalue their cultural knowledge in order to achieve in school science and mathematics*.

School science

The sections above have clarified some major challenges, and in some cases outright barriers, facing Indigenous students who want to prepare for a STEM-related occupation or career. Given the severity of these challenges, it is not surprising that Saskatchewan Indigenous students' persistence in completing the last three years of high school within three years is lower than for non-Indigenous students at present: 72% for all Saskatchewan students, 33% for self-identified Indigenous students (Saskatchewan Ministry of Education, 2011). The data for completing the last three years of high school within five years are 81% and 48%.

In Saskatchewan, a high school diploma requires a Grade 10 science credit, plus one credit from any 20 or 30 level science course. However, more science credits are necessary for students wanting to keep their options open for post-secondary programs. As indicated in Table 2, three major conclusions are apparent. First, there has been a decrease in the overall enrolment in 'optional' science courses over the past nine years. Between 2002 and 2011, Saskatchewan's enrolment dropped by 15% (from 52,637 to 44,514), in spite of an 8% increase in the province's population over the same time.

Table 2. Comparative Registrations in Grades 11 and 12 Sciences (Level 20 and 30 Courses) for Indigenous Students: 2002 Versus 2011 in Saskatchewan

Courses	All Sask. Students in 2002-2003	Self-Declared Indigenous Students in 2002-2003		All Sask. Students in 2011-2012	Self-Declared Indigenous Students in 2011-2012	
Biology 20	10,595	787	7%	9,702	1,568	16%
Biology 30	10,122	696	7%	9,141	1,397	15%
Chemistry 20	9,181	548	6%	8,106	906	11%
Chemistry 30	6,953	274	4%	5,932	464	8%
Computer Sci 20	2,042	119	6%	964	89	9%
Computer Sci 30	805	19	2%	288	25	9%
Physics 20	7,205	273	4%	5,891	444	8%
Physics 30	5,734	142	2%	4,490	255	6%
Total =	52,637	2,858	5%	44,514	5,148	12%

Based on Saskatchewan Ministry of Education, SDS-Discoverer, September 10, 2012. Registrations in science 20 and 30 courses are for all schools in Saskatchewan. A course assessment mark is required for the registration to be counted.

This constant decrease in student enrolment has been found in industrial countries worldwide. Students' views of the school science curriculum are usually blamed. For example, most research indicates that the curriculum is mainly experienced as socially sterile, impersonal, frustrating, intellectually boring, and/or dismissive of students' life-worlds and career goals (Aikenhead, 2006). Because this perception prevails even for science-proficient students who enrol in senior physical science courses in high school (Lyons, 2006), imagine the views Saskatchewan Indigenous students must hold. The most cogent single force acting against enrolment was found to be the culture of school science itself.

Second, Indigenous students' enrolments in optional science courses in Grades 11 and 12 between 2002 and 2011 *increased* 80% (from 2,858 to 5,148). This increase cannot be fully accounted for by the approximate 45% increase in Canada's Indigenous population over the same time period. A small portion of the 80% can be explained by more students self-declaring their Indigenous ancestry in 2011 than in 2002, which would reflect progress in Indigenous students' feeling comfortable in self-declaring. An upward trend towards 80% in Indigenous students' enrolment in 20 or 30 level science courses during the last two years of high school is noteworthy. Something good has been happening.

A third conclusion arises from Table 2: there is much more for Saskatchewan schools to accomplish. In 2011, Indigenous students accounted for 12% of the enrolments in 20 or 30 level science courses; but overall, Indigenous students accounted for 20 and 24% of the student population in Grades 11 and 12, respectively (Saskatchewan Ministry of Education, 2011). In other words, the proportion of Indigenous students opting out of 20 or 30 level science courses is much higher than for their non-Indigenous counterparts.

To begin to address these major challenges, many Canadian ministries and departments of education have revised or soon will be revising education policies to attract more Indigenous students into school science and mathematics to encourage them into STEM-related post-secondary programs. A well-known way to do this is to explicitly include Indigenous knowledge (Indigenous ways of living in nature) in a school subject (Aikenhead & Michell, 2011; Kanu, 2011; Richards et al., 2008). In science courses, the two knowledge systems – Eurocentric-based STEM and Indigenous knowledge – are complementary; they co-exist. When teachers have implemented such curricula, they have learned to build cultural bridges between their own culture of school science and their students' local Indigenous culture (Belczewski, 2009; Cajete, 1999, Ch. 7; Herbert, 2008).

Teachers also reported that benefits accrue for their non-Indigenous students (Kanu, 2011). School science and mathematics, enhanced by Indigenous perspectives, are for the benefit of both Indigenous and non-Indigenous students.

Turtle Island's 'Native Science Academy' (no date), which represents the scholarly interests of Indigenous peoples living in the United States and Canada, promotes the inclusion of Indigenous knowledge in school science.

> Native American learning is one form of understanding the natural world and the artificial [scientific] paradigms and context of conventional [scientific] knowledge. Native American languages and knowledge contain a vast body of wisdom and intimate understandings of interdependence and interrelationships. … Over the last decade university and secondary educational institutions have begun to recognize and value this knowledge.

> The inclusion of Indigenous Knowledge within the educational and scientific communities is a fragile and momentous event. Many new collaborations are required, and there is great potential benefit in such collaborations. But for such possibilities to be realized, mainstream perspectives must open themselves to Native knowledge [and] its study and learning processes, just as Native cultures have opened themselves to the study and benefits of mainstream strategies. (Retrieved December 27, 2012, from http://silverbuffalo.org/NSA-ScienceOfLearning.html)

Exemplifying this openness, Saskatchewan's Ministry of Education began a systemic science curriculum renewal in 2005 (Aikenhead & Elliott, 2010). The former curriculum contained language that encouraged teachers to initiate the inclusion of Indigenous perspectives in their science teaching, but no specifics were defined as required course content. This caused Indigenous perspectives to be ignored for a number of practical reasons; for example, (1) the lack of time teachers have to do the appropriate research to find Indigenous content to teach, (2) the lack of curriculum development expertise and writing skills required to do this research, and (3) the professional commitment of teachers to follow the required course content specified by the science curriculum.

But in 2008, Saskatchewan's school science program (Grades 6-9) dramatically changed in two important ways: first the curriculum's content specified Indigenous knowledge to teach, and then supportive teaching materials in the form of a science textbook series were developed for Saskatchewan schools. Indigenous Elders and educators were involved in identifying Indigenous knowledge for curriculum content (Aikenhead & Elliott, 2010). As a result, Indigenous knowledge was explicitly recognized, along with scientific knowledge, as a legitimate way to understand the physical world. Scientific knowledge became *one way* to understand the physical world, not *the only* way. Indigenous knowledge became integrated into each unit of study in an attempt to avoid tokenism, a situation that often happens when Indigenous knowledge is presented in a stand-alone unit of study or as an add-on to a unit of study (Ninnes, 2000).

Currently, Grades 1-9 school science, enhanced with Indigenous knowledge, is being implemented in Saskatchewan (http://www.curriculum.gov.sk.ca/#). This renewed science curriculum was designed to achieve scientific literacy for students of Euro-Canadian, Indigenous, and other heritages. Four learning contexts are specified: scientific inquiry, technological problem solving, STSE[4] decision making, and cultural perspectives. The *cultural perspectives* learning context conveys the fact that Eurocentric science is culturally anchored in paradigmatic communities of practice, most of which are Eurocentric in character, and the fact that Indigenous knowledge is anchored in local, placed-based Indigenous cultures.

The Saskatchewan vision of scientific literacy is articulated through four foundations of scientific literacy: to understand STSE, to construct knowledge, to develop skills, and to develop attitudes. The foundation called *construct knowledge* specifies domains of content to learn:

> Students will construct an understanding of concepts, principles, laws, and theories in life science, in physical science, in earth and space science, and in *Indigenous*

[4] STSE refers to a science-technology-society-environment approach to science education. It has been a major feature of Saskatchewan's science curriculum since 1989.

> *knowledge of nature*; and then apply these understandings to interpret, integrate, and extend their knowledge. (emphasis added)

Indigenous knowledge of nature is one of four knowledge domains to teach.

To identify the content to be constructed, a series of *outcomes* have been written in fairly broad terms. Outcomes related to Indigenous knowledge of nature are respectfully integrated among the three conventional science content domains. For example, the following Grade 6 outcome related to Indigenous knowledge is found within the life science domain in a unit called Diversity of Living Things:

> Outcome DL6.2 Examine how humans organize understanding of the diversity of living things.

The breadth and depth of each outcome are clarified through a representative list of *indicators*. For outcome DL6.2, the following two Indigenous knowledge indicators are found among several science indicators:

d. Explore local First Nations and Métis methods of organizing their understanding of living things (e.g., two-leggeds, four-leggeds, winged-ones, swimmers, trees, and grasses) and the criteria underlying their understanding (e.g., where animals are found, how animals move, and the uses of plants).
e. Describe how aspects of First Nations and Métis worldviews (e.g., holistic, interconnectedness, valuing of place-based knowledge) shape their understanding of relationships and responsibilities among plants, animals, and humans.

A Grade 9 example of an Indigenous knowledge indicator that clarifies a science outcome in the unit Atoms and Elements is the following:

> Outcome AE9.2 Analyze historical explanations of the structure of matter up to and including models of the atom: Dalton, Thomson, Rutherford, and Bohr model of the atom.

c. Describe specific ways in which First Nations and Métis Elders make sense of the physical composition of the universe.

Collaboration between the Ministry of Education and the publisher Pearson Education Canada led to the development of a series of science textbooks, *Pearson Saskatchewan Science* (Pearson, 2009-2012), which integrate Indigenous knowledge throughout the textbooks' science topics, including: interviews with Elders, descriptions of Indigenous knowledge, end-of-section questions, experiential activities, and inquiry projects. Indigenous Elders decided what content would be included in a science unit, and they controlled how that content was described. The production of these textbooks expanded the authority and responsibilities of Indigenous leaders. More than being consulted, they were *active co-participants*. The result is authentic place-based Indigenous knowledge to be learned.

The specific Indigenous content found in the textbooks helps clarify the curriculum's outcomes and indicators for teachers. The textbooks' Indigenous content is a useful place to begin when formulating a teaching lesson. The genre of the textbook writing was edited to ensure that both knowledge systems were treated as co-existing ways of understanding nature. Detailed teacher resource binders contain, for instance, background knowledge, specific teaching suggestions, and possible answers to questions. The textbooks are helping support teachers in implementing Saskatchewan's enhanced science curriculum.

Because Indigenous knowledge is place-based – valid for one place – the perspectives of local Indigenous communities are expected to be taught. This is a critical point. School systems must initiate contact between teachers and local Elders or Knowledge Keepers or Holders[5]. Professional development programs must support science teachers in developing relationships with these Indigenous people so that teachers can learn the local content to be taught, and often, how to teach it. This is how most teachers begin their journey into understanding Indigenous perspectives, and how teachers fulfill their responsibility as citizens in Canada's era of reconciliation.

In order for a professional development experience to be effective, a two-day (or longer) culture immersion activity must initially take place with Indigenous Elders (Aikenhead, 2012; Chinn, 2007). This activity has an emotional impact on most teachers, particularly when they learn firsthand from those who personally suffered from Canada's attempts at cultural genocide and the resulting disruptions Canadians are living with today. Teachers who have been through this experience explain it this way: only when your heart becomes engaged, does your brain begin to formulate successful action to take; in this case the implementation of Saskatchewan's renewed science curriculum with the help of Indigenous Knowledge Keepers (Aikenhead, 2012).

This curriculum implementation needs to be guided by the results of research into six areas:

1. student learning, with specific attention to the needs of Indigenous students (i.e., a cultural perspective on learning anchored in a student's cultural wellbeing)
2. Indigenous knowledge integrated into science classes (i.e., the course's content, processes, and contexts)
3. teaching strategies and methods (i.e., culturally appropriate pedagogy)
4. student assessment (i.e., culturally valid ways for students to communicate what they know)
5. culture-based patterns or styles of classroom interpersonal communication (i.e., teacher-student interactions and student-student interactions)
6. the learning environment that results from a teacher's holistic integration of these first five areas (i.e., an environment subjectively experienced by Indigenous students; not one described by academics and their 'objective' research methods and instruments.)

Collectively, this cluster of six areas has been referred to as *culturally responsive science teaching* (Aikenhead, 2012). Each aspect is summarized here.

Student learning

Conventionally worldwide, school science usually attempts to socialize or enculturate all students into the culture of academic science, replete with its canonical knowledge,

[5] A Knowledge Keeper or a Knowledge Holder is a respected Indigenous person to whom people go to gain help or understanding related to a specific issue or event (e.g., using plants for healing purposes). They are expected to pass this understanding on to the next generation.

skills, and values. Many science teachers want all their students to be able to think like a scientist, behave like a scientist, and believe what scientists are purported to believe. But this goal cannot be met except for the small proportion of students who, like the science teacher, have worldviews that harmonize with the worldviews endemic to the sciences; in other words, most students' worldviews differ, to varying degrees, from a scientific worldview conveyed by conventional school science (Aikenhead, 2006). Forty years of research on this issue were synthesized as follows:

> Discordant worldviews create an incompatibility between, on the one hand, students' self-identities (e.g. who they are, where they have been, where they are going, and who they want to become) and, on the other hand:
>
> - students' views of science, school science, or their science teacher, and
> - students' views of the kind of person they think they must become in order to engage in science. (Aikenhead, 2006, pp. 107-108, supporting citations are omitted)

Students who do not feel comfortable taking on a school science identity (i.e., being able to think, behave, and believe like a scientist) represent the vast majority of any student high school population in Canada and the United States; about 90% according to various research studies (Aikenhead & Elliott, 2010). In other words, Indigenous students are obviously not alone in feeling the same way as their non-Indigenous counterparts. Of course, a few Indigenous students do very well in school science because their personal worldview can embrace a worldview conveyed in their school's science program; this is their 'gift.' These students should be identified and specifically encouraged to continue to develop their gift. Some post-secondary institutions and industries in Saskatchewan are beginning to accomplish this outreach activity (see the sections 'University STEM-Related Programs and Projects' and 'Access to STEM-Related Employment').

As a result of *cultural identity clashes* (described above in 'Cultural and Linguistic Contexts'), most students tend to experience school science (Grades 6-12) as a foreign culture to varying degrees. Because their teachers do not treat it that way, these students must learn to set aside their own everyday cultural ideas, skills, and values to meet the expectations of their science teacher (Aikenhead, 2006). Most students, Indigenous or non-Indigenous, feel alienated and tend to resist such instruction, or they find ways to pass the course without engaging in meaningful learning. 'Empirical evidence demonstrates how students and many teachers react to being placed in the political position of having to play school games to make it appear as if significant science learning has occurred even though it has not' (Aikenhead, 2006, p. 28).

It is helpful to understand meaningful learning in terms of students *expanding* their cultural identities in ways meaningful to them, through their experiences in school science. In other words, to learn science meaningfully is to engage in identity work. This 'culture identity work' happens in holistic and/or in compartmental ways unique to each student (Aikenhead & Jegede, 1999). A cultural perspective on learning described here draws on features of a student's cultural identity, which include:

- the cultural resources they bring from their community into the classroom
- their self-identities: who they are, where they have been, where they are going, and who they want to become
- their individual gifts
- their 'recurrent learning strengths' (10 are itemized in the Appendix).

These features of cultural identity are central to culturally responsive science teaching.

The British Columbia Ministry of Education (2008) helpfully summarized nine 'First Peoples Principles of Learning'.

- Learning ultimately supports the wellbeing of the self, the family, the community, the land, the spirits, and the ancestors.
- Learning is holistic, reflexive, reflective, experiential, and relational (focused on connectedness, on reciprocal relationships, and a sense of place).
- Learning involves recognizing the consequences of one's actions.
- Learning involves generational roles on responsibilities.
- Learning recognizes the role of Indigenous knowledge.
- Learning is embedded in memory, history, and story.
- Learning involves patience and time.
- Learning requires exploration of one's identity.
- Learning involves recognizing that some knowledge is sacred and only shared with permission. (p. 11)

These should be incorporated into all culturally responsive STEM school programs.

Scientific and Indigenous knowledge integrated in science classes

The science content and Indigenous content to be taught come from two knowledge systems that describe and explain nature in complementary ways, described above in the subsection 'Culture and Linguistic Contexts'. The province's science curriculum and local Elders or Knowledge Keepers/Holders provide guidance on what content is to be taught. Indigenous students find this Indigenous content interesting and relevant; it tends to diminish some of the alienation they would otherwise feel towards their science classes (Aikenhead & Michell, 2011). Many non-Indigenous students become eager to engage in activities and projects that open up this new worldview to them (Aikenhead, 2012). A British Columbia study of 366 public schools over a period of five years found that Indigenous students increased their achievement when Indigenous content was incorporated into the curriculum (Richards et al., 2008). This research also resulted in 'improving relations with Aboriginal families and community members, and transforming expectations in schools' (p. 14).

The *relevancy characteristic* of both scientific and Indigenous content connects most students to their everyday world. This contrasts with the abstract content of academic science and mathematics courses that often seems relevant to only a minority of students whose worldviews harmonize with a decontextualized, intellectual, abstract world; and which therefore seems irrelevant to the vast majority of students. All students see their everyday world through the prism of their worldview.

Cultural differences become apparent between typical scientific-mathematical thinking and typical ways that Indigenous Knowledge Keepers or Holders think. Both ways of thinking need to be honoured and celebrated for their contributions. The nature of science suddenly becomes relevant as it emerges naturally from discussions contrasting the two types of knowledge systems – the predominantly Eurocentric system of STEM and the Indigenous system of ways of living in nature.

Relevancy is well known as a strong intrinsic motivator for students' success in STEM (Aikenhead, 2006). Relevancy has been defined in terms of seven different perspectives based on who decides what is relevant (Aikenhead, 2006, Ch. 3). Relevant curricula certainly help counter Indigenous students' feelings of alienation in the school system (Aikenhead & Michell, 2011, Ch. 2). What do most STEM employers think is relevant science content to be taught in schools and universities? The short answer is that they give specific predetermined content the lowest priority among all the factors they take into consideration when hiring someone. The long answer and its implications for schools are found in the subsection 'Employer Expectations' below.

Teaching strategies and methods

There are culturally appropriate instructional strategies and teaching methods that help engage Indigenous students in the content to be learned. Methods that harmonize with or enhance Indigenous students' cultural identities can be layered onto a teacher's current repertoire of methods. Culturally appropriate methods include: story-telling, talking circles, observing followed by emulating, diverse visual sensory ways of gaining information, scaffolding (i.e., various types of guidance and feedback), students writing exit notes, reflective journaling, community support, collaboration in effective group work, Elders or Knowledge Keepers/Holders as visitors in a classroom, teaching out of doors in the land, field trips to Indigenous cultural events, and teaching directed towards the community's wellbeing (Aikenhead & Michell, 2011; Kanu, 2011). When life-long learning is the ultimate goal, a trustworthy teaching strategy is getting students to make significant, responsible and autonomous choices (Aikenhead, 2012). For all students, the most *successful teaching methods* are those that actively engage students intellectually, physically, emotionally, and sometimes spiritually. All students respond well to experiencing a variety of teaching methods, but especially those methods that draw upon students' needs and recurrent learning strengths (the Appendix).

Culturally valid student assessment

Culturally appropriate assessment and evaluation strategies give feedback to students and their teacher about what is being learned and the effectiveness of the instruction (Aikenhead, 2012). Assessment for learning is emphasized to avoid a typical complaint Indigenous students often express: 'My science teacher tests me to see *what I don't know*; he doesn't give me a chance to show him *what I do know*.'

Various assessment strategies encourage students to express what they have learned. For example, teachers use: exit comments (i.e., short notes written by students at the end of a lesson, which point out something learned and/or something felt), reflective journal entries, portfolios, experiential problem-based reports, and clearly written open-ended test questions. Some strategies are as simple as providing effective reviewing sessions prior to a test and providing sufficient time for Indigenous students to complete a test or lab. Indigenous students often translate a question into their own language or worldview and then back-translate their thoughts into English, a necessary process that takes extra time. (For an example, see the subsection 'The Case of Deborah' below.)

Culturally valid assessment builds on students' cultural assets to encourage achievement ('the asset model' of teaching that contrasts with 'the deficit model'). A teacher takes into consideration students' home language and their cultural values, beliefs, experiences, communication patterns, and recurrent learning strengths (refer to the Appendix). Teachers attempt to minimize implicit biases of schools, of school science and mathematics, and of their own background (summarized in the subsection ‘Political Climate/Context’ above). These are biases towards one’s own taken-for-granted cultural ideas hidden within one’s language, social institutions, and history. Recognizing such biases in the first place is often called ‘maintaining a critical stance’. This skill is very important to culturally valid assessment.

Culture-based interpersonal communication

Patterns or styles of teacher-student interactions and student-student interactions are about different ways people express themselves. How do they talk, for instance, when they communicate knowledge, values, feelings, humour, and authority? The focus here is on both verbal and nonverbal interpersonal interactions that make students feel welcome, safe, and respected in a classroom. Without paying attention to this personal aspect of teaching, there can be little progress in becoming successful at implementing new content, new pedagogy, and improved assessment practices.

Interpersonal interactions in classrooms are idiosyncratically personal, and they are historically loaded with cultural conventions and biases. A teacher’s culturally appropriate interpersonal style needs to convey respect, humility, a sense of caring, firmness in guiding student behaviour, encouragement to forge relationships among students, faith in students’ autonomy and responsibility, and high expectations of academic achievement (Aikenhead, 2012; Aikenhead & Michell, 2011; Kanu, 2011).

Learning environment

A teacher’s holistic integration of the first five areas described here will define a learning environment as experienced by Indigenous students. The most *successful* learning environment actively engages students intellectually, physically, emotionally, and sometimes spiritually. This is crucial for engaging Indigenous students in STEM learning. A culturally appropriate learning environment becomes an operational definition for culturally responsive science teaching.

Conclusion

Six areas that comprise culturally responsive teaching in school science lead to many positive consequences for Indigenous students (Aikenhead & Michell, 2011; Barnhardt et al., 2000; Brayboy & Castagno, 2008; Kanu, 2011). These consequences include: increased science and mathematics enrolment, better classroom behaviour and engagement, higher motivation to learn, greater school retention rates, beliefs in being able to meet a teacher’s academic expectations, standardized science achievement on par with the general population, academic achievement in general, ecological literacy specifically, and consideration of science-related careers or occupations. These lead to more Indigenous students choosing post-secondary STEM-related programs. Other positive consequences for Indigenous students were observed to be: stronger cultural self-identities, greater self-esteem, respect for Elders, self-directedness, and a desire to become voices of conscience for sustainability. Positive consequences for non-Indigenous students have also been documented (Kanu, 2011).

A group of science teachers in Saskatoon, Saskatchewan, participated in a professional development project that focussed on developing their capacity in culturally responsive science teaching (Aikenhead, 2012). Eight of the teachers wrote stories about some of their experiences. These stories are replete with positive responses from their students, Indigenous and non-Indigenous, for example:

- listening with focused abject attention
- willing and eager to immerse themselves in Indigenous-related activities, and sometimes spiritual ceremonies
- being seriously engaged in learning Indigenous knowledge and understanding Indigenous perspectives
- questioning out of personal interest
- initiating conversations with students of a different culture
- taking personal responsibility
- helping to create a community of learning within a classroom
- reflecting on reasons that explain how students live out their daily lives in a privileged way and according to specific cultural stories they have been told
- arranging to engage their peers in a Smudge (an Indigenous cleansing ceremony involving smoke that draws one's spiritual aspects into one's consciousness in a way that strengthens one's personal spirituality).

Besides a better understanding of Indigenous perspectives, non-Indigenous students tended to gain a much deeper understanding of their own culture's scientific way of knowing nature. By learning the similarities and differences of both knowledge systems, non-Indigenous and Indigenous students alike tended to identify hidden or taken-for-granted assumptions found in the science they were learning.

Another Prairie Province research project was undertaken to explore the components and themes to successful school STEM programs for Indigenous students. Sutherland and Henning (2009) in Manitoba carried out a literature analysis and then an interactive action-research project with 50 science educators from schools with programs that facilitated Indigenous students' academic success. Sutherland and Hemming's literature analysis identified four components to successful programs: coming to know (a holistic, experiential, wisdom-oriented way of learning), cross-cultural pedagogy (culturally responsive ways of teaching), social and ecological justice (including the power relationships and social dynamics in science education), and ecological literacy (a field more related to Indigenous knowledge than most other fields in science education).

By engaging school personnel experienced in Indigenous science education, Sutherland and Hemming (2009) facilitated a series of discussions that began with the participants' reaction to the four components above, and ended with four key themes the participants distilled from their discussions about what makes school science programs at their schools successful for Indigenous students. Their four themes were: Elders, culture, language, and experiential learning. Each of these was defined by a list of attributes generated by the participants. Finally, the researchers synthesized the components and themes into a two-dimensional grid as a framework for a cross-cultural science education strategy (a 'life long learning model'; p. 187).

Indigenous students have the intellectual potential to learn to master and utilize STEM without, in the process, sacrificing their own cultural ways of knowing nature. Culturally responsive school science nurtures walking in both worlds – Indigenous and Euro-Canadian. In the Mi'kmaw Nation in Eastern Canada, some Elders talk about two-eyed seeing that emphasizes the strengths of both knowledge systems (Hatcher, Bartlett, Marshall, & Marshall, 2009). By walking in both worlds or by two-eyed seeing, Indigenous students gain cultural capital essential for accessing economic and social power as citizens in a Eurocentric dominated world while maintaining their roots in an Indigenous wisdom tradition.

There is a great deal of work yet to accomplish in Saskatchewan before achieving equity for Indigenous students' completing high school and entering post-secondary institutions with the satisfactory prerequisite STEM skills, understandings, and values assumed by those institutions. Saskatchewan has specific programs designed to help students and young adults augment their competencies to meet the expectations of post-secondary STEM-related programs. This could be called a 'patch-work' approach to the issue, if you will, but it is a pragmatic short-term way of helping to eliminate the under-representation of Indigenous employees in STEM-related occupations. These transition programs are described below in the sections 'STEM-Related Technical or Professional Institutes/Colleges' and 'University STEM-Related Programs and Projects.'

School mathematics

School mathematics and physics have long been known to screen students to locate 'the best and brightest' and invite them into the STEM post-secondary 'pipeline' so they eventually enter science-related professions (Posner, 1992). Students who are most likely to fail this screening process are those who belong to marginalized social-economic groups (Apple, 1979; Hughes, 2000; Nasir, Hand, & Taylor, 2008). The screening process also provides high status and social power to the more privileged students who make it through. This is the reality facing all students participating in most mathematics learning environments in Saskatchewan, but especially Indigenous students.

Along with high status school subjects such as mathematics and physics comes the paucity of pressure on educators to defend or rationalize the content included in the school curriculum for those subjects (Venville, Wallace, Rennie, & Malone, 2002). The politics of privilege inhabit school mathematics and physics courses (Carlone, 2003) and directly impact Indigenous students' experiences in mathematics and physics learning environments, especially for on-reserve schools.

The pedagogy of school mathematics can dramatically change depending on the social economic status (SES) of a school's neighbourhood, as shown in Anyon's (1980) ground-breaking research. She discovered that children in high poverty working-class areas tended to be taught mathematics by following memorized algorithms, while at the other end of the SES spectrum, children in CEO-family areas tended to be taught through exploration, creativity, decision making, and convincing others to subscribe to one's preferred solution to a mathematics problem.

Similarly, mathematics education may vary considerably from country to country. For this reason, this section on mathematics education delimits its scope to the Province of Saskatchewan. The reader is free to transfer to their own setting any perspectives or conclusions that appear in this report, as seems appropriate to the reader.

Although mathematics and sciences differ widely in their ontologies (beliefs about reality), their epistemologies (ways of knowing that reality), and their school curriculum histories, they share some important features in the context of STEM education (in part described above in the section 'School Science'). For example, they both employ languages initially foreign to most people, and they both tend to alienate many students (Hogue, 2011). The culture of school mathematics often clashes with a student's worldview or cultural identity (Davison, 2002). For instance, by representing things, events, and persons by numbers (e.g., IQ scores), quantification encourages some people to believe that they can objectify a thing, event, or person by stripping the person of their qualitative, human, or spiritual attributes by means of representing them with a number. From an Indigenous perspective, enriched by subjective relationships and responsibilities with everything in Mother Earth, objectification through quantification can show a lack of respect at the very least, and can border on oppression at worst, depending on the context. That explains why many Canadian Indigenous languages did not have a need for an elaborate mathematics system before contact with Europeans.

Objectification through mathematics is a value that can cause serious culture clashes for Indigenous students and as well for non-Indigenous students whose worldviews do not resonate with a quantitative perspective on their everyday world. Yet numeracy, mathematical representations of events, and mathematical problem solving are valuable cultural capital in occupations related to STEM in our modern economy. Thus, cultural clashes must be resolved by acknowledging and respecting Indigenous values and by nurturing students' cultural self-identities so that learning mathematics does not mean devaluing their cultural heritage. Indigenous knowledge has an appropriate place in school mathematics (Davison, 2002; Perso, 2003).

Another source of alienation arises from the fact that a mathematical knowledge system (e.g., sets, proofs, angles, algebra, and geometry) is an abstract representation that can often be superimposed on the physical world; the system does not arise from empirical evidence from the physical world, as it does in science. Although effective instruction in both mathematics and science contextualizes subject matter in the familiar world of students (e.g., the world of First Nations and Métis students), the task is much more challenging for mathematics teachers.

The culture of school mathematics clashes with many Indigenous students in Australia, as well: 'Number does not carry the deterministic weight or the aura of objectivity and inevitability that it carries in non-Aboriginal Australia' (Watson & Chambers, 1989, p. 32). Pioneering work that articulated mathematics as a cultural phenomenon came from Alan Bishop's (1988) scholarship in Australia. All human knowledge is cultural, including mathematics (Goldstein & Goldstein, 1981). The Aboriginal families of Western Australia had invented a very sophisticated mathematical system that was unlike the globalized system taught today in schools around the world. Family relationships permeated the foundations of their mathematics. 'Whereas non-Aboriginal people use number patterns based on counting and measurement, the patterns used by Aboriginal people [in Western Australia] are based on relationships between people [a genealogical pattern]' (Perso, 2003, p. 20). This sophisticated mathematics, which some Indigenous people superimposed on their everyday world, was incomprehensible to British colonizers, and remains a challenge to Eurocentric thinking today. Although it was both sophisticated and useful to Australian Indigenous peoples, this genealogy-based mathematics system was not a priority in their culture.

The incorporation of mathematics into science can be quite alienating to Indigenous students. In the words of Dr. Hogue (2011) of Métis ancestry:

> This fixation with quantifying science, in my opinion, is why Aboriginal people do not do as well in the sciences, particularly the physical sciences based upon measurement. It removes the *livingness* and as a result the experience, much like Residential School removed them from family and culture. (p. 307, emphasis in the original)

In the context of explaining the ways of thinking in high status scientific paradigms, Aikenhead and Michell (2011) pointed out the role of quantification in scientific thinking:

> The presupposition of quantification assumes that the material world is governed by objective mathematical relationships. Theoretical physicists are prone to say 'the language of nature is differential equations.'… Concepts such as the complexity of life, for instance, are not considered scientific unless they are measurable (Hazen, 2005). (pp. 52-53)

Lakota Elder Deloria (1992) critiqued this presupposition of science from his Indigenous perspective:

> The present posture of most Western scientists is to deny any sense of purpose and direction to the world around us, believing that to do so would be to introduce mysticism and superstition. Yet *what could be more superstitious* than to believe that the world in which we live and where we have our most intimate personal experiences is not really trustworthy, and that *another mathematical world exists that represents a true reality*? (p. 40, emphasis added)

This is indeed an important culture clash that needs to be addressed by mathematics educators.

Aikenhead and Michell (2011) concluded:

> (1) the two-dimensional Greek world of Euclid is an idealized abstract way of thinking about the world, with many practical uses;
> (2) the practicality of the Euclidean system today has made it attractive to most nations worldwide, where it has been either freely imported by a nation or exported by a colonizing nation;
> (3) Euclidean geometry is taught in schools the world over, not because it is reality [truth], but because it is useful. (pp. 53-54)

Of course, some students (Indigenous or non-Indigenous) will feel comfortable in most school mathematics and physical science classes if their worldview harmonizes with a quantification perspective on understanding one's experiences. For instance, Ed's narrative in Hogue's (2011) research with Canadian Indigenous STEM scholars describes how his gift in mathematics was noticed and encouraged at a very young age by his family, but it was not until high school did educators take notice. He eventually earned a Ph.D. in mathematics and is now a university professor.

On the one hand, topics in school mathematics tend to be more decontextualized, abstract, philosophical, and rigid than science topics, and therefore mathematics is often seen as being more difficult to learn (Nasir et al., 2008). But on the other hand, students are subjected to more pressure to succeed at mathematics because of the high value society places on that achievement (Venville et al., 2002).

The Saskatchewan mathematics curriculum appears to include an Indigenous perspective on the world by drawing upon Indigenous artefacts to teach some mathematical concepts (http://www.curriculum.gov.sk.ca/#). The curriculum's introduction lists four goals: logical thinking, number sense, spatial sense, and mathematics as a human endeavour. This last goal creates promising opportunities to deal with Indigenous perspectives, for example (quoted from the curriculum):

- value place-based [Indigenous] knowledge and learning
- value learning from and with community
- encourage and value varying perspectives and approaches to mathematics
- value and honour reflection and sharing in the construction of mathematical understanding.

Teachers are directed to create experiences for students to develop 'an understanding of mathematics as a way of knowing the world'. This is to be achieved, first by empowering 'teachers to understand that mathematics is not acultural. As a result, teachers then realize that the traditional ways of teaching the mathematics are also culturally-biased'. More holistic and constructivist approaches to learning are encouraged as follows (quoted from the curriculum's introduction):

> Mathematical ideas are valued, viewed, contextualized, and expressed differently by cultures and communities. Translation of these mathematical ideas between cultural groups cannot be assumed to be a direct link. … Various ways of knowing need to be celebrated to support the learning of all students.

To identify ideas that appear in this introduction, the curriculum specifies outcomes and indicators. Unlike the science curriculum, the mathematics curriculum has no outcome that addresses Indigenous knowledge. There are, however, indicators related to Indigenous knowledge. For instance, six indicators are found in the Grade 6 curriculum, while 11 are found in the Grade 9 curriculum. One typical example is: 'Describe examples of where First Nations and Métis, past and present, lifestyles and worldviews demonstrate one or more of the *circle properties* (e.g., tipi and medicine wheel)' (emphasis added). Note that the phrase 'circle properties' refers to the objectified, decontextualized and mathematical meaning of the term 'circle.' It does not refer to the subjective, holistic and spiritual meaning of circle embraced by Indigenous cultures. The curriculum's indicator merely encourages placing conventional mathematical ideas in an Indigenous context. Although this exemplifies culturally appropriate teaching methods, it completely ignores culturally appropriate content by omitting an Indigenous perspective or worldview on the topic at hand. This characteristic of the mathematics curriculum does not meet the culturally responsive standard found in the province's science curriculum. The high expectations created by the mathematics curriculum's introduction are disappointingly superficial in the details of the curriculum's outcomes and indicators.

Unlike the school science program, there has been no progress in producing mathematics teaching resources (e.g., textbooks, monographs, or websites) or formulating professional development programs, which concretely clarify what it means to include authentic Indigenous perspectives in school mathematics. The curriculum is inadequate in terms of culturally responsive mathematics teaching.

The prospect for enhancing Saskatchewan's Indigenous students' achievement in school mathematics continues to rely on the conventional pressure on students to persevere and work harder. No movement has occurred to reconfigure Indigenous students' self-identities as 'math hunters' or 'young warriors of math' in the new buffalo for mathematics achievement. The place-based spirituality of the circle, for example, would be one place to begin, provided that a group of Elders concurred during a co-participation process. Both Indigenous and non-Indigenous students deserve nothing less.

Research into Indigenous students' university experiences

Research reveals significant features in university STEM programs and projects that either discourage and dissuade Indigenous students or encourage and help sustain them. The discouraging features are examined in the subsection 'Leaving the STEM Pipeline,' while both types of features are clarified in 'The Case of Deborah' and 'Successful Indigenous STEM Graduates.'

Leaving the STEM pipeline

As a baseline to research into Indigenous students' experiences in post-secondary STEM programs, it is instructive to examine a few highly relevant research findings concerning all students' experiences in post-secondary STEM programs. Consider, for instance, the STEM 'pipeline' data from a 15-year longitudinal study, beginning in 1977, conducted by the US Office of Technology Assessment with an initial sample of 4 million Grade 10 students, mostly non-Indigenous one can presume. One critical statistic needs to be highlighted: The drop-out rate for students enrolled in university undergraduate STEM programs in the US was about *twice* that of high school science programs (39% : 19%) (Frederick, 1991). Thus, the rate determining step (to borrow a chemistry metaphor) towards gaining a science or engineering degree occurs at the university undergraduate level. Therefore, any problem associated with insufficient science personnel for business and industry rests at the feet of university and college STEM departments. These quantitative data are supported by in-depth qualitative research that concluded that the problem of qualified students (Indigenous or non-Indigenous) moving out of the STEM pipeline resides much more with universities and colleges than with high schools (Lee, 2002; Tobias, 1990). Therefore, the problem of Indigenous students' under-representation in STEM-related occupations demands a critical analysis of what transpires during post-secondary STEM programs.

One crucial question to investigate is, 'Why is it that science departments are unable to attract and retain those who are the most qualified to excel in science education and related professions?' (Adamuti-Trache & Andres, 2008, p. 1578). The answer deals with the practices, attitudes, or culture of university departments that harbour an *entitlement* to accept and to discourage students; rather than the responsibility to attract and retain students (Tobias, 1980). Some exceptions exist, of course. But generally speaking, universities need to enact quality STEM programs that do not dissuade or marginalize qualified students from finishing their program. According to a number of research studies, STEM university success depends, in part, on students being able to 'negotiate a culture characterized by white, masculine values and behavioural norms, hidden within an ideology of meritocracy' (Carlone & Johnson, 2007, p. 1187). As a result, Johnson (2007, p. 818) concludes, 'Without the need to impute ill will, prejudice, or discrimination, Black, Latina, and American Indian women are being disadvantaged'. These research findings at the university level (see also Daniell, 2006; Malone & Barabino, 2009) describe a discouraging and dissuading culture in many university science and engineering departments.

This is the culture in which future science teachers hone their professional self-identities and belief systems as school teachers, as well as forge allegiances to the culture of academic science. As a consequence, the culture of university science and engineering departments – a culture that tends to discourage certain groups of students – becomes reproduced as the culture of school science. The net effect is an ethos of discrimination and alienation of students who historically have been marginalized in school science. Ending this vicious cycle is an admirable project for universities and colleges to take on.

The case of Deborah

The experiences and ultimate success of Deborah, a university B.Sc. biology major proud of her Diné (Navajo) ancestry, were systematically followed by Brandt (2008). Deborah had always loved science in school. When attending high school, she decided to become a physician to help her people in New Mexico improve their standard of health and ensure their cultural survival. Deborah's story, summarized in Aikenhead and Michell (2011, pp. 100-103, 141-142), illustrates some of the complex challenges faced by Indigenous students as they attempt to master a Eurocentric science without losing their Indigenous way of thinking, reflecting, and being.

When confronted with difficult scientific concepts, Deborah tried putting them into the familiar context of her Diné thinking and speaking. Invariably, she had trouble doing so because the worldviews associated with each language were so different. In frustration, she told one instructor, 'A lot of what you are saying I can't understand because it's not in my world' (Brandt, 2008, p. 837). It was not until her fourth year at university when Deborah finally realized that she needed to distinguish between *understanding* a scientific idea and *believing* it. This conceptual distinction lifted a tremendous weight off her shoulders. Instructors would not even discuss with her the cultural clashes she experienced with her Diné worldview, let alone help her resolve them. Nor did any instructor show her how to challenge or question scientific ideas. 'They give this evidence and there's no argument. … [they assume] it must be true', explained Deborah (p. 835). She often referred to science as a process of 'belief' rather than a process of evaluating scientific data. Instructors would tell her just to accept it. Their attitude made Deborah feel like an outsider who was expected to devalue, or even abandon her own identity and take on one similar to the professor's, a universalist ideology. She resisted this process of identity cloning (Tobias, 1980).

Like many Indigenous peoples around the world, Deborah understood that everything is spiritually imbued. In Diné culture, there are proper protocols, prayers, and ceremonies involved when taking the life of an animal. Offerings are made in order to restore balance in Mother Earth. The Diné foundational concept of harmony conflicted with biology when she was expected to dissect frogs and work with cadavers with emotional detachment – 'invading others' as Deborah called it. She concluded that this invasion 'disrupts the harmony within ourselves and then we are not the person we should be' (p. 836). Deborah also held strong beliefs in the Diné Creation Story and the origins of her people. This grand narrative conflicted with scientific evolution and natural selection. 'Deborah was not asking to remove evolution from the … curriculum. She was asking her professor for guidance' on how both views might co-exist in her mind (Brandt, 2008, p.

839). It was some time before Deborah was able to accept the existence of both stories without having to sacrifice one over the other. She learned to understand one while believing the other. No instructor helped her do this. Meaningful dialogue to explore uncertainties with one's science professors was absent in the culture of her university science.

Deborah had the good fortune to be hired by a molecular biology research laboratory during the summer between her third and fourth years. Unlike her experience in academic courses where discussion about her culture clashes was unacceptable, she found her laboratory coworkers and mentors to be much more open. They helped her communicate in the culture of microbiology. She could ask questions, challenge their ideas, and make connections between the biological knowledge she had previously memorized and specific lab procedures. She formed relationships with these people, unlike her experience with instructors. She began to understand science in a deeper, more meaningful way, which in turn led her to adopt strategies for completing a BSc program with her Diné identity intact. 'What I'm learning from my non-Navajo world will help my people health wise. But what I've been brought up with, it's there. I'll always believe my creation story' (p. 836). Deborah finally realized that Diné tradition and Western medicine could be *complementary* and promote harmony at the same time. Her newly gained point of view allowed her to risk participating in biology without having to change her beliefs. Instead, she could temporarily suspend any paradoxes with her Diné world. The two cultural ways of knowing nature began to co-exist for Deborah, thus lessening the risk of culture clashes.

Deborah achieved high grades during her fourth year at university because she had learned how to succeed in an educational system without losing her cultural identity. Her instructors, however, needed to develop a balance between teaching science and acknowledging Indigenous worldviews, a culturally responsive balance that emphasizes academic achievement and students' cultural identities (Brandt, 2008). Deborah thought the professors expected her to abandon her Diné worldview. She needed an instructor who appreciated the cultural challenges she faced daily and who would talk with her once in awhile in an open personal dialogue of humility, respect, and trust. This would have helped her move back and forth between the two cultures more smoothly and with less psychological risk.

Deborah's story highlights the importance of fostering supportive peer relationships and establishing classroom environments that honour and respect Indigenous perspectives. Indigenous students in general face many systemic barriers that keep them from entering or succeeding in post-secondary STEM programs. In particular, Deborah's story speaks to the challenges caused by worldview clashes, and the role of language in those clashes. Instructors need to consider allowing longer response times when asking questions, so that an Indigenous student has time to make the necessary cognitive translations before answering. For example, instructors could pose key questions at the beginning of a unit, or a week, or a lesson; questions that give students guidance in identifying the main points of the instruction. This would allow time for students to reflect on what they know, to sort out their thoughts, and to respond in a more holistic manner. Some of these questions might appear on a unit examination. At the same time, Indigenous students must learn the languages and vocabulary appropriate for different scientific contexts in order to function professionally in collaboration with mainstream society.

Brandt (2008) pointed out how cultural barriers around science departments serve instructors, providing them with 'a position of legitimacy', 'a location of credibility', and 'a place of power' (p. 838). As a result, instructors build a moat around their professional identity as science professors without thinking about building bridges across that moat to Indigenous students. Ongoing personal dialogues with Indigenous students make excellent bridges. Deborah's instructors likely held 'the widespread belief that scientific knowledge transcends culture and therefore science instructors do not need to [concern themselves with matters of culture]' (p. 839).

Successful Indigenous STEM graduates

Deborah's challenges were also faced by successful Canadian Indigenous students as they persevered through university STEM programs to earn a bachelor, masters, or doctorate degree and are now involved in STEM-related careers. Michelle Hogue's (2011) Ph.D. research examined the narratives of 13 Indigenous people, a subset of whom I shall call 'the multifarious six' for the purpose of this report. Hogue, who is of Métis ancestry, discovered *how* this group of six succeeded in their academic STEM programs where so many Indigenous students do not. Each of these six had a very different upbringing, a much different set of life circumstances, a unique cluster of academic capabilities, and a totally different career goal. As a consequence of this diversity, Hogue adds considerable richness to our understanding of what makes a difference for success in STEM programs; in other words, our understanding of what these six people needed in order to succeed. Therefore, this research informs post-secondary institutions and instructors as to what needs to be created or replicated in order to support their Indigenous students who might otherwise exit their STEM programs.

In general, the multifarious six were able to develop and experience satisfaction in a *life-space* that can be constructed between

- a Eurocentric way of understanding the world, exemplified by Canadian education institutions, their customs and language, STEM beliefs about reality, and STEM ways of describing and explaining that reality, and
- an Indigenous way of understanding the world, exemplified by Indigenous languages, customs, beliefs about reality, ways of coming to know that reality, and ways of living properly in that reality.

This life-space between two incommensurate worlds is neither a 'gap of deficiency' (Hogue, 2011, p. 6) nor a hybrid of the two worlds (p. 250), but rather a space of respectful dialogue and humility to be inhabited by people of each culture – Euro-Canadian instructors and Turtle Island Indigenous students. The evidence for having adequately reached such a life-space comes from the experience of being able to move back and forth fairly comfortably between the two cultures. The multifarious six, as well as Deborah (above), succeeded in their academic STEM programs when they developed the capacity to be 'cultural oscillators' (Hogue, 2011, p. 20). Any post-secondary institution that can orchestrate the development of Indigenous students becoming cultural oscillators will almost certainly go a long way to enhancing the STEM capacity of those students. Becoming a cultural oscillator was a necessary condition for the success of the multifarious six. To ensure success for other Indigenous students, university instructors and other personnel need to become cultural oscillators themselves. This is a vital part of a blueprint for creating or replicating for other Indigenous students what the multifarious six possessed to succeed.

How did these six develop their capacity for cultural oscillation? Although each one followed a different path, Hogue ascertained two attribute categories – vision and agency – both of which are necessary for success. Each is described here, because they form the details of a post-secondary institution's blueprint for success for Indigenous students.

First, the multifarious six had at sometime in their life a vision of themselves in a role related to STEM, which required a university degree or a technical institute diploma. Ester who is one of the six and now a medical doctor stated, 'It is about getting that image or visualizing yourself as being a nurse, a doctor, a scientist, or an engineer, something other than the stereotypical identity of Indians imposed by society' (Hogue, 2011, p. 163). Such a vision was strong enough for these six people to combat the forces of racism, poverty, neo-colonialism, and unexpected turn of events. It was strong enough to bring some of them back to the STEM pipeline when instructors, administrators, or life's circumstances forced them out of the pipeline. An implication is evident: it would not be a waste of resources to nurture Indigenous school children's visions of themselves being employed in STEM-related occupations. Indigenous role models are important here.

Second, Ester continues, 'And then it is about finding your way and making your way. There are people to help along the way but ultimately it is up to you' (p. 163). How does one make things happen? Hogue labelled such wherewithal 'agency' (p. 92). Agency embraces cognitive, social, and personal aspects. Cognitive agency is exemplified by formulating a strategy for accomplishing something (p. 209). Acquiring social agency comes from the people who one gets to know and who turn out to be supportive, especially mentors in one's home community, post-secondary institution, or workplace. Acquiring personal agency provides one with: will or inner strength (p. 201), perseverance (p. 203), resilience (p. 214), drive to honour one's parents (203), being a hard worker (p. 123), sense of self-worth (163), a sense of having the right to achieve one's vision or dream (p. 163), and an openness to change or to augment one's identity (i.e., identity work, described in the section 'School Science' above) (p. 163).

Personal agency of Indigenous or non-Indigenous students can explain why some people succeed while others do not. Neurological and psychological research into personal agency points to qualities we associate with character or personality traits; that is, non-cognitive skills such as: curiosity, conscientiousness, optimism, delayed gratification, grit, and self-control (Tough, 2012). The narratives of the multifarious six pinpoint specific personal agency traits developed in their upbringing through interacting with grandparents, parents, teachers, other students, and Elders, as well as from their reaction to adversity. The multifarious six, in one way or another, had developed agency that caused them to consciously work towards acquiring STEM skills and capabilities, along with working to understand institutional cultural customs in order to realize their visions. In Hogue's words (2011, p. 210),

> Each of the interviewees has their own agency, had incredible strength and perseverance that enabled them to stay with it when it became challenging, but importantly they took action into their own hands and were able to make things happen rather than wait for others to initiate and they did not blame others if things did not work according to plan.

Many Indigenous students enter universities not having such agency, yet those students have the potential to learn STEM skills and capabilities as long as they do not exit the STEM program. It is clear from Hogue's conclusion that post-secondary institutions should adopt projects or programs that *initiate things to happen*, rather than expect Indigenous students to enter their STEM program with the 'incredible strength and perseverance' shown by the multifarious six. An example of a blue-print-for-success program is described in the subsection 'Undergraduate Indigenous Student Support' (below).

But most importantly, the six 'maintained their cultural identity and integrity' (p. i) throughout their STEM program. Therefore, it would not be a waste of resources to nurture Indigenous students' cultural identities, in one way or another, as they study STEM throughout their years of education. One nurturing avenue to follow, for example, is to transform the conventional status-quo *privilege* enjoyed by post-secondary instructors (described in the subsection 'Political Climate/Context' above) into a privilege for instructors to enter into respectful and open dialogues between themselves (who represent the cultures of STEM disciplines housed in an academic institution) and the Indigenous students who are struggling to become cultural oscillators in that institution. This experience will be very rewarding to the STEM instructors who participate.

STEM-related technical or professional Institutes/Colleges

Saskatchewan is home to a number of STEM-related technical institutes and regional colleges established under the jurisdiction of the government's Ministry of Advanced Education, Employment, and Immigration. Most institutes and colleges have campuses throughout populated regions of the province to accommodate students. Some are affiliated with one of the province's three universities and offer entrance-level university programming. Some are contracted by STEM employers to offer education opportunities for staff; from short courses on a mine sight, for example, to enrolment in a program that leads to a specific certificate or diploma. A number of their courses cater to entry level employment in technology occupations such as: practical nursing, aircraft maintenance engineering, radiologic technology, pharmacy technology, electronics, heavy industry, resource-based industries, agriculture, and the technical trades. These post-secondary institutions have been effective in reducing First Nations unemployment in Saskatchewan from 30% in 2001 to about 21% today (Cooper, 2012), but there is ample room to continue this decrease.

The largest and most academic-oriented technical institute is the Saskatchewan Institute of Applied Science and Technology (SIAST), which has campuses specializing in different fields, and which offers varied instructional approaches for a diverse clientele (http://www.gosiast.com/). Campuses are located in four of the province's cities, all in southern Saskatchewan. SIAST has invested human and financial resources to establish an Aboriginal Services department that offers an array of support for Indigenous students, including: a Summer Transition Support Program; an Emergency Bursary program; and Aboriginal Activity Centres that provide social interaction and various support services to students, including access to Elders and cultural advisors.

Two institutions are run by Indigenous political organizations. The Saskatchewan Indian Institute of Technologies (SIIT, http://www.siit.ca/) was established about 11 years ago by the Federation of Saskatchewan Indian Nations (FSIN). SIIT provides relevant trades and industrial programming for First Nations people offered at the First Nation community level and geared to the economic interests of the Band Council in each area. SIIT offers a variety of work-skill development, apprenticeship and industrial programs. Emphasis is placed on the construction trades. The second Indigenous institution, the Dumont Technical Institute (DTI), was established about 18 years ago by the Gabriel Dumont Institute (GDI, http://www.gdins.org/) that serves the Métis Nation in Saskatchewan. The DTI develops a skilled Métis workforce that meets local, regional, and national labour market needs by focussing on: adult upgrading, essential skills, practical nursing, and computer science. These two Indigenous institutions naturally provide culturally appropriate support programs for their students.

Affiliated with the teacher education programs at the University of Saskatchewan and the University of Regina, two Indigenous fully accredited Bachelor of Education four-year degree programs prepare First Nations and Métis teachers. These graduates are fully certified to teach anywhere in the province, but they are encouraged to return to their communities to be a role model for Indigenous achievement in the academy. Since 1972 the Indian Teacher Education Program (ITEP, http://www.usask.ca/education/itep/) has prepared mostly elementary school First Nations teachers. It is based at the University of Saskatchewan in Saskatoon but has satellite course offerings at selected reserves. Since 1980 the Saskatchewan Urban Native Teacher Education Program (SUNTEP, http://www.usask.ca/education/suntep/index.php) has also offered a B.Ed. degree for Métis students, run by the GDI at three urban centres. Both ITEP and SUNTEP have the potential for growth by developing a program for secondary school science and mathematics teachers in the future. Indigenous students interested in teaching STEM subjects enrol in the B.Ed. program offered to all students but receive cultural and academic support in ITEP or SUNTEP.

A third teacher education institute is the Northern Teacher Education Program (NORTEP, http://nortep-norpac.webs.com/) that provides a four-year, off-campus program for northern residents, which leads to a Bachelor of Education degree in cooperation with the University of Regina and the University of Saskatchewan. Because 85% of northern Saskatchewan's population is Indigenous, NORTEP enrols a high proportion of Indigenous students. Its location in the northern region of the province is advantageous to northern students. As mentioned below, NORTEP is awaiting funding for a science centre so it can offer more in-depth STEM-related programs for future teachers. A science emphasis in the Elementary Program was developed several years ago and is offered through the University of Saskatchewan.

Because of the unique situation of northern Saskatchewan, there is a regional college that meets northern Saskatchewan's special needs, the Northlands Community and Technical College, which has three campus locations (http://www.northlandscollege.sk.ca). Northlands College offers certificates and diplomas for aviation, computer networking, and health occupations, as well as vocational technical programs geared towards industry employable skills, particularly the mining sector. It functions co-operatively with northern businesses and industries.

The Northern Professional Access College (NORPAC) and NORTEP are combined into one organization – NORTEP-NORPAC (http://nortep-norpac.webs.com/). It began on a small scale in 1976 offering some university courses in the town of LaRonge, well situated in northern Saskatchewan to be more accessible to residents in isolated towns, villages, and reserves. NORTEP-NORPAC purchases courses from the Universities of

Saskatchewan and Regina to deliver in the north. It now offers up to three years of university Arts and Science courses, though STEM courses are not prominent due to the lack of laboratories. A major funding initiative holds promise for a substantial science facility to be built in LaRonge. The instruction model created by NORPAC has been most successful. It follows strict university standards balanced with culturally responsive student support and course content that reflects northern Saskatchewan's needs. For example, mathematics courses draw upon northern employment contexts to teach concepts and skills. Academic study is balanced with practical applications. One-on-one instruction is readily available through classroom tutors. Intensive periods of study alternate with reading weeks that allow students to return to their communities to finish assignments and projects. This helps alleviate pressures arising from parents being away from their families. Some courses maintain an interface between NORPAC and work sites. From time to time, NORPAC responds to unexpected labour shortages in the north by training cohorts of students. In terms of academic STEM programs, NORPAC has graduated 40 students with biology or geology university degrees. Currently a Masters of Education is being offered mostly for northern teachers. One of its three streams focuses on STEM. A new science laboratory facility will give impetus to this graduate program.

University STEM-related programs and projects

This section describes various types of programs and projects helpful for increasing Indigenous university students' STEM capabilities. School outreach projects target students prior to their enrolment at university. Other projects support students during their transition from high school to university, or during their undergraduate program. The section ends by illustrating STEM-related university-level programs specifically developed for Indigenous students but open to non-Indigenous students if space permits.

School outreach projects

The Universities of Regina and Saskatchewan run school outreach projects that see university personnel visit on-reserve schools and northern schools to encourage Indigenous students to think seriously about attending university. These brief encounters provide students with a profile of what university has to offer and what high school courses are prerequisites for admission to various STEM-related programs. In another type of outreach project aimed at motivating student interest in a STEM career, science professors travel to a school and talk to science classes and perhaps show them something fascinating about what they investigate. In the words of Indigenous researcher Hogue (2011), the intention is to stimulate a student's *vision* of themselves as being a scientist, health professional, engineer, or science teacher (see the subsection 'Successful Indigenous STEM Graduates' above).

For example, a stimulating outreach project, 'Wildlife CSI' (CSI is a television pop-culture acronym for 'crime scene investigation'), was initiated by Dr. Ryan Brook in the College of Agriculture and Bioresources at the University of Saskatchewan. His scientific research entails wildlife, land and resource management for Indigenous communities; community-based ecosystem monitoring; human-wildlife conflict; and climate change impacts on landscape change. During school visits, Dr. Brook enacts Wildlife CSI with students. They find it fascinating because it helps them connect the science with their everyday world. Students learn how to appropriate school science content to understand the research he shares with them. He involves them in authentic activities that interpret real evidence. Because this research involves collecting data from Euro-Canadian hunters and from Indigenous subsistence hunters, Dr. Brook teaches students about Western and Indigenous knowledge systems and how they complement each other. Sometimes the content is purely Western science and sometimes it comes from Elders. He helps students make sense out of both. Wildlife CSI builds STEM capacity for Indigenous and non-Indigenous students in rural and Indigenous communities, some of which are isolated northern communities. During the past 18 months, he has visited 23 schools throughout Saskatchewan and Manitoba, which brought him into contact with about 1450 students. Wildlife CSI is funded by PrionNet Canada.

A major outreach program, Science First (http://www.scifi.usask.ca/), began in 1989 by undergraduate students in the College of Engineering at the University of Saskatchewan and has been expanding by about 20% per year ever since. It now goes by the name 'SCI-FI Science Camps'. The program delivers hands-on science, technology, and engineering experiences to school-aged youth in a fun way. Camps have reached more than 15,000 students a year through classroom workshops (60-minute presentations during May and June), community programs (year round), science clubs (on Saturdays), as well as single day-camps in more than 20 locations across the province. The most in-depth experiences occur at the week-long summer camps held on campus in Saskatoon during July and August. Several types of summer camps are offered, for example: Science Camps, Technology Camps, Computer Science Camps, Medical Science Camps, and Veterinary Medicine Camps. Through the generous support of funding agents, SCI-FI Science Camps are able to deliver programs across Saskatchewan and provide some financial bursaries to those students who would not otherwise be able to attend.

Although Indigenous youth are not specifically targeted by SCI-FI Science Camps, Indigenous students have participated through satellite camps held in northern communities from time to time, and they have participated in Saskatoon programs when they have received bursaries to defray camp fees and other expenses.

SCI-FI Science Camps also holds a day-long 'Discover Engineering' event each year. It introduces Grade 8 girls to various types of engineering. They learn about the many job opportunities available for them after completing an engineering program. Throughout the day, they meet role models who have chosen a career in engineering.

Such short lived encounters are worthwhile when they engage students, as the examples above do. However, school visits rarely lend themselves to forging a relationship between university STEM representatives and individual Indigenous students. The reality of an Indigenous world is characterized by a holistic web of strong interrelationships and the responsibilities that attend to those relationships. An Indigenous emphasis on relationships contrasts with a conventional Eurocentric academic's reality of individualism and self-initiative. Such a contrast undermines the overall effectiveness of outreach projects for Indigenous students; notable exceptions not withstanding.

Saskatchewan's third university, the First Nations University of Canada (FNUC), has a natural on-going relationship with on-reserve schools and with their communities. These relationships ensure culturally rich connections between Indigenous students and FNUC. This takes the place of a formally organized outreach project.

The Science Ambassador Program at the University of Saskatchewan is a much different outreach project because it is based on STEM people building strong relationships with Indigenous students and their science teachers (http://www.ourscienceambassadors.com/). The representatives (ambassadors) from university science programs are expected to learn about Indigenous cultures while Indigenous students learn STEM content by engaging in activities created by an ambassador for science lessons the teacher plans on teaching. The Ambassador Program calls this 'two-way learning.' It is an encounter of mutual sharing that holds potential to create a 'life-space' for cultural oscillators that Hogue (2011) wrote about in her research (described in the subsection 'Successful Indigenous STEM Graduates' above).

Ambassadors are chosen from 3rd and 4th year undergraduate students, or graduate students, enrolled in degree programs in science, engineering, and the health sciences. They are paired with remote schools that have a high percentage of First Nations and Métis students. Individual or pairs of ambassadors live for five to six weeks in a remote community in Saskatchewan, Alberta, or Manitoba. The ambassadors receive an honorarium for their work, which represents about half of the Ambassador Program's yearly budget. Participating schools value these science ambassadors as peer mentors and role models for their students. Ambassadors are also valued as professional development resources for science teachers.

Ambassadors' jobs include:

- acting as a 'science contact' for teachers
- providing engaging demonstrations and hands-on science experiences to students
- participating in extra-curricular science-related activities
- mentoring senior students about opportunities for continuing education and
- engaging with the community by participating in school and cultural events.

Teachers report that they mostly appreciate the ambassadors' effort to align their hands-on activities with curriculum objectives, to modify activities so they are age and grade appropriate, and to bring the elements of fun and novelty into their classrooms. For example, one teacher wrote, 'The kids listened because the ambassadors caught their interest. I learned off of them as well. All the experiments were interesting and also helpful to me. I learned a bit more and every bit counts!' Teachers also see their students' interactions with university students as a positive contribution towards their students' motivations and ambitions for 'higher level learning'.

By giving Indigenous students opportunities for successful engagement in science, ambassadors counteract conventional student attitudes that usually dismiss STEM disciplines as boring, irrelevant, and/or difficult. Ambassadors follow the motto '*making science fun and relevant, one community at a time*'. As a result, the University of Saskatchewan forms learning partnerships with teachers, schools, and communities, and it engages schools in a dialogue to enhance STEM education.

Since 2007, 29 science ambassadors have been placed in 18 communities throughout the three Prairie Provinces, having reached over 4,570 students by the end of the 2012 visits. Feedback from student questionnaires and qualitative reports by teachers and school administrators indicate a positive correlation between time spent with science ambassadors and student attitudes towards: enrolling in higher level science classes, considering jobs in science and engineering, and viewing the success of women in these careers. In 2012, 12 science ambassadors worked with a total of 59 teachers, reaching 1,070 students, 81% of whom self-declared as having an Indigenous ancestry. Science ambassadors were matched with communities based on best fits between their areas of study and the needs in the schools.

The ambassadors worked in the communities between mid-April (the end of univer final examinations) and early June (nearing the end of the school year). They were housed by their communities in band-owned teacherages, divisional housing, industry-sponsored housing, and/or educational facilities. These relatively long-term placements allowed the science ambassadors to engage with the community, enjoy and learn from the natural environment, and build meaningful and lasting relationships with students, teachers, and community members. An Indigenous perspective and focus on a relational world was taken seriously in planning the Science Ambassadors Program. It is a model of culturally appropriate STEM programming.

Indicators of success for the Science Ambassadors Program include results such as:

- Students in 2012 responded to a survey question ‘How excited are you to take high school science?’ with an average response of 8.5 on a 10-point scale, where 10 meant ‘very excited’ and a 1 meant ‘not at all’.
- All University of Saskatchewan science ambassadors would recommend other students to apply to be a science ambassador.
- Every 2012 participating community indicated that it would like to host science ambassadors again in 2013. The Ambassador Program, however, has a greater demand for ambassadors than can currently be accommodated.
- Written comments from teachers, administrators, and students are overwhelmingly positive.

To the question, ‘How do you rate your experience with the Science Ambassador Program?’ the following female/male student responses were tallied (respectively):

‘Didn’t like it’	1% / 8%;	‘Nothing special’	3% / 3%;	‘Liked it a little’	1% / 7%;
‘Good’	27% / 29%;	‘Very good’	41% / 47%;	‘Amazing’	53% / 40%

On a pre-post student questionnaire, the following results were found for two questions:

‘A job of a scientist would be good’:	pre ‘yes’: 41%	post ‘yes’: 62%
‘A job of an engineer would be good’:	pre ‘yes’: 48%	post ‘yes’: 55%

Probably the most significant assessment information is that school attendance rose each time students knew that an ambassador would be in their science classroom. Sometimes the increase was dramatic, for example, a teacher’s expectation of 3 students one afternoon turned out to be 22 students out of a class of 25. Teachers, of course, were amazed.

The Science Ambassador Program is supported by the Colleges of Medicine, Nursing, Veterinary Medicine, Kinesiology, and Pharmacy and Nutrition at the University of Saskatchewan; as well as the International Centre for Northern Governance and Development. The Program receives funding from the University of Saskatchewan, the Government of Saskatchewan, the National Science and Engineering Research Council, an organization called Women in Science and Engineering, various industries such as

Cameco and AREVA Resources Canada, and other educational organizations depending on which remote northern communities are visited by ambassadors.

Transition programs

Transition programs from high school to university entrance are offered by technical and profession institutions described above, and by universities. Typically they are for young adults who do not meet the academic expectations of university entrance, but who wish to acquire a STEM university degree. Some university STEM programs offer non-credit courses for students to upgrade their STEM skills, but these on-campus offerings require students to live in Saskatoon or Regina. The culture shock of moving away from rural remote communities or reserves into a large Euro-Canadian urban centre is a major hurdle for most Indigenous students to negotiate. This has severely restricted the success of these types of transition offerings.

However, a culturally appropriate transition program has been established by the First Nations University of Canada (FNUC, http://www.fnuniv.ca/), which is affiliated with the University of Regina. FNUC has recently added a STEM program to its usual degree programs of teacher education, nursing, social work, and native studies. This community-based STEM program is aimed at supplying a professional, university-educated workforce for Saskatchewan's energy, mining, and resource asset management sectors. The transition program at FNUC is based on best practices accumulated over recent years. The program has three components which overlap to help many students complete it within 12 months or at their own pace. For this 2012-2013 preliminary year, 30 Cree First Nations students on the Onion Lake reserve have enrolled. In partnership with the University of Regina, instructors travel to the Onion Lake reserve to teach these students. The program will expand each year to include more than one reserve.

The first component of the program addresses life skills for surviving in a city (e.g., formulating a budget, fundamentals of banking, and rent contracts). The second component addresses skills such as academic reading, writing, mathematics (from arithmetic to pre-calculus), and is comprised of 10 courses at a pre-university level. A transition certificate is earned. The third component offers 10 success-based courses that extend students' mathematics and science skills to an introductory university level. Mathematics, chemistry, First Nations resource management, and geography can be studied. A completion certificate is earned for admission into engineering and applied sciences at the University of Regina, located adjacent to FNUC.

A student enters the three-component program at a point commensurate with the student's skills. For example, students can begin somewhere during the second component. Transition from one component to the next is seamless due to their overlapping nature, which creates a high degree of flexible individual programming. Throughout this transition program, students strengthen their Indigenous identities through culture immersion activities at their reserve.

The program's third component overlaps with university introductory studies in mathematics, chemistry, physics, and geology, which includes tutoring support for students and optional labs for alternative ways to learn STEM content. The FNUC transition program dramatically reduces the alienating atmosphere of first-year university

STEM courses identified by Hogue's (2011) research (described in the subsection 'Successful Indigenous STEM Graduates' above).

Undergraduate Indigenous student support

Due to Canada's privacy legislation, the universities in Saskatchewan do not make public detailed statistics that could describe proportions of Indigenous students enrolled in specific programs and courses. Only published general census data can be reported. STEM enrolment data and trends for Indigenous university students are highly confidential.

The academic content taught in mainstream STEM programs at universities certainly follows the Eurocentric (Western) way of knowing the physical universe. Unlike school science curricula, university STEM curricula will not include Indigenous perspectives, and most Indigenous students do not expect them to. The idea of culturally responsive STEM teaching gains little support in universities. This is a given that must be accepted for the time being. As described in the section 'Research into Indigenous Students' University Experiences', almost all STEM professors refuse to discuss Indigenous perspectives with students. As a consequence, support for undergraduate Indigenous students has traditionally occurred entirely outside the venue of course work in STEM programs.

Like the Saskatchewan Institute of Applied Science and Technology (SIAST) and other Canadian technical institutes and universities, the University of Saskatchewan has a centrally located Aboriginal Students' Centre (ASC) that promotes the mental, emotional, physical and spiritual wellbeing of all Indigenous students on campus. It is a relaxing and inclusive gathering space for students to talk, use a computer, get help communicating with funding agencies, or access various student services available to all students and particularly to Indigenous students; for example, academic skills workshops, information sessions, various support programs on- and off-campus, traditional teachings, pipe ceremonies, Sweat Lodges, and access to traditional Elders. The ASC organizes a major day-long 'Pow-Wow' Indigenous celebration ceremony at the beginning of each new academic year for all university students, Indigenous and non-Indigenous. At the ASC, Indigenous students who are new to the campus can learn about campus life and how to get involved. Mentorship programs are set up for those who ask for them. Monthly social functions offer opportunities for students to connect with each other. As a walk-in centre, the ASC relies on students initiating their involvement, which can be a challenge for students feeling alone, disconnected, and unsure of themselves. Similarly, Indigenous students enrolled in STEM classes in the past were invited to take advantage of specific STEM support meetings such as tutorial sessions and study groups, but the invitational nature of those support meetings undermined their effectiveness that their designers had anticipated.

To overcome student reticence to become personally involved in, and committed to, the campus STEM academy, a very innovative Aboriginal Student Achievement Program (ASAP) was implemented in the university's College of Arts and Science on a pilot basis this year. It is open to first-year students: who have self-identified as being Indigenous, who have met the regular Arts and Science entrance requirements, who are on campus for the first time, and who have opted to become involved in this innovation. One incentive to enrol in the ASAP this pilot year was the increased chance of receiving financial support. ASAP takes on more of an Indigenous ethos, rather than the Western academic ethos that characterized former student support programs. For instance, ASAP does not invite students to create an Indigenous community of learning for themselves, ASAP is organized as a community of learning, in a way comfortable to most Indigenous students.

This year's pilot focuses on biology, but the program will expand to include most STEM first-year courses in the future. Sixty Indigenous students are currently enrolled in one of several three-class triads per semester. For example, in the first semester, students chose one triad among the following triads of courses: (a) Biology, English, and Psychology; (b) Biology, Native Studies, and Learning to Learn; or (c) Biology, Political Studies, and Sociology. Students select a fourth and fifth course per semester, which are taken along with the general population of first-year university students, this year.

Triad classes are kept unusually small, with a limit of 30 students. Instructors have been specifically chosen, based on their understanding of the needs of Indigenous students and their wish for the relative intimacy of small classes and the chance to forge professor-student relationships; exactly what Deborah was asking for (see the subsection 'The Case of Deborah' above). Student advisors are assigned to each triad to offer their continuous expertise. For each course in a triad, the Arts and Science department offering the course hires tutors who are available throughout the semester at scheduled tutorial sessions. Biology has about 12 tutorials planned this year, for instance. Each triad is also mentored by an alumni STEM graduate currently employed by a company or government agency. Mentors and advisors help students set academic and career goals. Without these goals, students do not have a guiding vision for themselves (described in the subsection 'Successful Indigenous STEM Graduates' above). ASAP has been designed to make first year university easier and more successful, rather than the formidable challenge it has normally been for Indigenous students.

In addition to sharing common classroom experiences, a triad of students comes together for a 'Learning Community hour' each week, guided by two successful senior Indigenous students. During these mandatory Learning Community hours, students: study together; develop study skills as needed; learn about career options in STEM; receive academic advice; listen to multidisciplinary panel discussions that emphasize a holistic perspective on their courses; engage in 'writing-to-learn' and story telling; critically discuss themes or issues that arise from time to time; participate in cultural events with Elders; and become involved in the larger campus community. Educators will recognize that an ASAP triad itself is a potent learning community that reflects many features of traditional Indigenous teaching/learning patterns. It is highly culturally appropriate with its rich network of relationship building.

As indicated in the examples of triads just above, students have the option of taking a course 'Learning to Learn', in which they construct a basic knowledge of cognition as it applies to learning, and in which they discover their own recurrent learning strengths (the Appendix) and how they can best use their strengths to succeed in their STEM program. Moreover, students are expected to apply what they learn to monitor their own lifestyle, decision-making, and self-regulation in an effort to improve their overall academic success.

ASAP develops an on-campus, Indigenous, STEM community that helps students improve their academic skills, their personal 'agency' (Hogue, 2011), and their savvy in surviving the academy. The program is being monitored for assessment purposes to guide its future expansion. Plans are being formulated to support first- and second-year students with a mathematics/science preparation class, which will prepare them specifically for entry level chemistry and mathematics courses required in their chosen STEM program. The Aboriginal Student Achievement Program anticipates that the successes accrued in its pilot year will attract more first-year students next year, and that its successes this year will have prepared its current first-year students for a successful second STEM year and beyond. The first two years of university are the critical years for most Indigenous students.

Indigenous STEM-related programs

Some Canadian universities are affiliated with Indigenous nursing programs or Indigenous teacher education programs that graduate nurses and a few STEM school teachers each year (described in the section 'STEM-Related Technical or Professional Institutes/Colleges' above). Some professors have established their own STEM-related research program that connects university personnel with specific Indigenous communities to solve problems that require both scientific and Indigenous ways of understanding. Although research participants learn valuable STEM content, these projects are more of an ad hoc arrangement than an established academic program developed at a university to target Indigenous students. Two notable STEM-related academic programs that respond to the needs of Indigenous communities are summarized here.

In 2001 in the province of Nova Scotia, Cape Breton University's award winning Integrative Science Program brought together scientific worldviews and a Mi'kmaw First Nations worldview in a series of four courses offered as credit towards a four-year BScCS (Bachelor of Science in Community Studies), housed within a university affiliate called the Mi'kmaq College Institute (Hatcher et al, 2009). Course content was approximately 80–85% scientific and 15–20% Indigenous. Given the label 'MSIT' (a Mi'kmaw word meaning 'everything together'), these courses emphasized relationships within nature. The four courses were:

- MIST 101/103. *Sense of Place, Emergence, and Participation*: the exploration of human consciousness including its brain-basis as understood in modern neuro and cognitive sciences, as well as the traditional worldviews of Indigenous peoples.
- MIST 201/203. *Ways of Knowing*: the exploration of ways of knowing about, and living within, nature, including Traditional Ecological Knowledge and modern ecosystem stewardship.
- MIST 301/303. *Cycles and Holism*: human understandings of cycles, rhythms, and transformations in nature, including scientific and Indigenous worldviews.
- MIST 401/403. *Wholeness*: human understandings of wholeness and change in nature by exploring such topics as health, disease, and healing.

Between 2001 and 2010, up to 15 students each year were enrolled in the first-year course (MIST 101/103), and each year a small number of students graduated with a BScCS having taken all four of the Integrative Science courses (Bartlett, 2012).

Since 2007, however, no new students have been admitted to the full Integrative Science Program. In 2010, the Unama'ki College replaced the Mi'kmaq College Institute at Cape Breton University. The Integrative Science academic program transferred from the Department of Biology within the School of Science and Technology to a new Department of Indigenous Studies within the Unama'ki College of Cape Breton University. As a result, the Integrative Science Program was placed 'on pause' and is waiting to be modified and re-invigorated. The first-year MSIT course is taught from time to time in Mi'kmaw communities.

A second university level STEM-related program to be considered here emerged from eight regional Indigenous land management groups who formed the National Aboriginal Lands Managers Association in 1999 (http://www.nalma.ca). They established a national certification program that offers professional education in Indigenous land management, either to introduce people to it or augment their expertise. The Level 1 Training certification program is housed at the University of Saskatchewan, while a Level 2 Technical Training certification program is delivered intermittently as the need arises by the National Aboriginal Lands Managers Association itself.

Level 1 Training is delivered by the College of Agriculture and Bioresources, University of Saskatchewan, through the Indigenous Peoples Resource Management Program (IPRMP) (https://agbio.usask.ca/index.php?page=pros-cert-iprmp#courses). It prepares Indigenous land managers from across Canada to deal holistically with environmental, legal, and economic aspects of land and resource management. STEM environmental content is one of the academic currents that flow through the courses. Because students come from all regions of Canada, their diverse backgrounds cause them to learn a great deal from each other. Students also acquire professional skills in communication, leadership, research, and project management. Upon completion, students earn a Certificate of Proficiency in resource management from the University of Saskatchewan.

To accommodate the working and family lives of its students, IPRMP is delivered through an intensive 'face-to-face format' on campus and by a 'home-study distance format' in the student's community. Classroom instruction (8:30 to 4:30 each day, and two evening-study sessions a week) is comprised of lectures, labs, and field-trips, which take place during the months of April, August, and January. Students' accommodation in Saskatoon is provided by IPRMP. Home study consists of readings, assignments, web discussions, and projects. Six university degree-level courses are divided into three study modules over a 12-month period. In the sixth and final course, a student conducts an R&D (research and development) type of project important to the student's community (e.g., a water protection project).

IPRMP connects academic achievement with students' community employment. Its Certificate of Proficiency allows students to enter the second year of a Bachelor of Science in Renewable Resource Management program at the University of Saskatchewan, if they wish.

This is the Program's sixth year in operation. Over this time, enrolment has remained relatively stable at about 33 students per year. At the end of the current year, IPRMP will have certified a total of 149 students, which represents an incredible 75% success rate for Indigenous students studying first-year university courses. This success rate is credited to the culturally appropriate ways in which Indigenous ways of learning are taken seriously and by the delivery structure of IPRMP that supports students far away from home while attending month-long classes in Saskatoon, and by the support extended to them in their home communities. A spiritual aspect of Indigenous learning has been added this year by integrating Elders and Knowledge Keepers or Knowledge Holders into field-trip activities.

Land management expertise of Indigenous communities has become central to their cultural survival in 21st century Canada, where some communities face incursions from the mining sector; for example, uranium in northern Saskatchewan (see subsection 'Two Mining Companies' below) and chromite mining in northern Ontario.

> The mining holds the promise of thousands of jobs over the next decade, if not longer – as long as the proposals can pass environmental muster and garner the support of the region's First Nations. But chromite also poses significant challenges to the environment that can be difficult to manage. (Scoffield, 2012b)

Cultural survival depends on sustainable development of Indigenous lands. In the past, industry has caused permanent mercury poisoning in the waters of some First Nations reserves in Ontario. Currently there is controversy over inedible fish in the 'poisoned' Athabasca River down stream from Alberta's bitumen sands processing industry (a.k.a. oil sands or tar sands development, depending on which side of the controversy one stands on). These evidence-based concerns over water quality are animated by Indigenous holistic views: 'It's not only fish, it's the animal kingdom. It's not only us, it's everybody. It's the planet. You can't jump [with] a careless plunge into development. You have to know what you're doing to your future' (Chief Moonis of the Marten Falls First nation, northern Ontario; quoted in Scoffield, 2012b). Chief Day of the nearby Serpent River First Nation explained: 'The protection of water is a sacred obligation to Indigenous people. Without clean water, life will cease to exist. Our obligation to protect water is an overall respect for life itself' (quoted in Scoffield, 2012b).

In other words, sustainability needs to be placed in at least four contexts: (1) the positive economic and social developments promised to the First Nations communities involved; developments that will last one or two generations but not necessarily for seven generations – the traditional time frame for serious decisions by First Nations communities; (2) the sacredness of water, one of the four dimensions to the physical world; all four of which are alive with Spirit that flows from Creator through everything; (3) the reciprocal obligation, duty, and promise to Creator to live in balance with the physical world in which humans' status is understood to be less than or equal to, but not above, the status of other entities in Mother Earth; and (4) the apparent dismantling by the federal government of its traditional environmental oversight of most lakes and rivers in Canada, which would create a void in the jurisdiction of responsible water management.

To achieve sustainable balance between mining and ecological interests, Indigenous communities require STEM-related transdisciplinary expertise in land management.

Access to STEM-related employment

A general context for understanding Indigenous graduates' access to STEM-related employment is provided by research into what STEM employers worldwide expect of all graduates from high schools and universities. This context is summarized first. Then two mining companies are described in terms of why they enjoy a highly favourable reputation for helping Indigenous students' to access STEM-related employment in northern Saskatchewan.

Employer expectations

A primary goal of STEM education is to prepare students for science-related occupations in, for example, industry, business, government, and the health professions. STEM curriculum developers expect students to integrate curriculum content into their own thinking so that this content becomes accessible for application later when students are employed in a science-rich workplace.

> Several research studies, however, have shown a poor match between the scientific content generally taught in high school and university science courses and the type of scientific understanding required for success in science-based occupations in which knowledge of the practice of science is either *critical* to the job or *enhances* occupational competence (Aikenhead, 2005, p. 243, original emphasis).

> Coles (1998) surveyed higher education specialists in science and United Kingdom employers to identify scientific content thought to be essential to school science. Unexpectedly the content found in the traditional science curriculum received very limited consensus across all respondents. The most valued qualifications were generic thinking skills and mathematical capabilities. Large United Kingdom organizations, such as the Chemical Industries Association and the Association for the British Pharmaceutical Industry, preferred their recruits to possess general capabilities rather than specific canonical science content (Coles, 1996). Desired capabilities included: commitment and interest; skills in communication, numeracy, and information technology; personal effectiveness, relationships, and teamwork; and initiative and creativity. Of lesser importance was the list of scientific capabilities sought by these employers (from highest to lowest priority): decision making by weighing evidence; scientific skepticism and logical thinking; and finally, *understanding science ideas*. (Aikenhead, 2006, p. 34, emphasis added)

In Beijing, Law (2002) interviewed expert scientists to learn what their hiring priorities were. She concluded:

> Contrary to much conventional wisdom and the practice of specifying lists of content as the key elements of a science curriculum, the study found that habits of mind, attitudes, and values figured more prominently than scientific content knowledge in the attributes identified by 'societal experts' as the most distinguishing qualities for success in their particular areas of expertise. (p. 151)

All the scientists in Law's study mentioned creativity, and several talked about a person's personal interest, perseverance, willingness to inquire, and ability to communicate; but a relatively low priority was given to 'having a broad or wide knowledge base' (p. 158). Very similar findings came from the research by Duggan and Gott (2002) in the United Kingdom, by Lottero-Perdue and Brickhouse (2002) in the United States, and Aikenhead (2005) in Canada.

Why do STEM employers place 'understanding specific scientific ideas' at the lowest priority for judging a recruit? Because the on-the-job science content used by STEM graduates at their place of work is so context specific it has to be learned on the job. High school and university science content is rarely drawn upon directly.

These research findings are not saying that STEM students need not learn science content. Instead, the findings are saying that it does not matter what STEM content is learned, as long as the content enhances students' capacity *to learn how to learn* scientific content *as the need arises* (i.e., within a relevant context) – preparation for life-long learning (Symington & Tytler, 2004). This is what STEM employers expect of STEM graduates. Learning *how to learn* science is an unspoken priority.

A major policy implication becomes clear: STEM educators should choose scientific and mathematics content based on its relevance to students, rather than solely promote the canonical content that has always been in a curriculum or the canonical content that university science, engineering, and mathematics departments invariably prescribe. The most effective school science and mathematics curricula that encourage students to enrol in optional STEM high school courses and university STEM programs are curricula constructed around students' cultural relevance, which motivates their engagement in learning (Aikenhead, 2006, Ch. 3; Tytler, Duggan & Gott, 2001a,b; Symington & Tytler, 2004). For instance, rather than discuss whether the curriculum topic of simple machines should be taught in Grade 5 or 6, STEM educators should investigate the question: Are simple machines culturally relevant for students to learn in school? and if not, remove the topic from the curriculum.

One cluster of STEM content, however, seems to be essential across most science-related occupations: concepts needed to think about or to critically analyze data and evidence – 'concepts of evidence' (Duggan & Gott, 2002; Gott, Duggan, Roberts, & Hussain, 2010). An encyclopaedia of concepts of evidence and their description is published on-line by Gott, Duggan, and Roberts (2012). Examples include: causation versus correlation, validity versus reliability, confidence limits, and instrument calibration. These STEM skills of data and evidence evaluation help answer such questions as: Is the scientific evidence good enough to warrant taking action now? (Aikenhead, 2005). Concepts of evidence are not normally found to much extent in most school STEM curricula, and they are not a priority in university STEM curricula.

In summary, key aspects that employers seek in employees include: thinking skills; knowing how to learn science content on the job; having mathematical capabilities required by the job; having the personal skills to be an effective team member; having the ability to communicate clearly orally and in writing; and possessing personal attributes reminiscent of Tough's (2012) non-cognitive skills such as: curiosity, conscientiousness, perseverance, optimism, interest, grit, and self-control. On the other hand, employers ignore, by and large, whether or not a prospective employee knows the specific canonical science found in a conventional STEM curriculum.

Two mining companies

Canada was the world's largest uranium producer for many years, accounting for about 22% of world output, until 2009 when it was overtaken by Kazakhstan. Two of the world's largest uranium producers are AREVA Resources Canada and Cameco. Both operate in Saskatchewan and have their head offices in Saskatoon.

As described in the subsection 'Demographic Context' (above), northern Saskatchewan has a sparse population residing in isolated communities (mostly villages and First Nations reserves), 85% of whom are people of Indigenous ancestry. Uranium mining has been developing in the north since 1976 and has been characterized by negotiation and collaboration among the mining sector, the Government of Saskatchewan, and northern residents. This history featured agreements over environmental impact on, and economic development for, these northern residents. The bottom line has always been northerners should benefit.

For example, surface-lease obligations set the following goal: 67% of a company's direct employees will be northerners. This refers to all company payroll jobs, STEM-related and others. Indirect employees are those hired by improvised local businesses (invariably First Nations businesses) that contract with mining companies to supply, for instance, food catering, security and janitorial services. Counting both direct and indirect employees, AREVA Resources Canada has reached the 68% mark, while for direct employees the figure has grown over the years to 50% and continues to rise as more northerners become qualified to enter the mining sector's workforce. Similar data describe Cameco. Both companies are committed to reach the 67% mark for direct employees (a badge of honour in northern communities), and both are moving beyond their past emphasis on entry-level jobs to give specific attention to enhancing career paths for northerners within their company. Although the two are competitors, they also enter into joint-venture projects.

The descriptions of the two companies written here offer insight into how Saskatchewan companies can increase the STEM capacity among Indigenous citizens, and how Indigenous STEM graduates from high schools, technical institutes, or universities access the labour market in Saskatchewan. By focusing on different features of each company, this description avoids comparing the two companies in any competitive way. AREVA Resources Canada is described first.

AREVA Resources Canada (http://us.areva.com/EN/home-156/areva-in-canada.html), a subsidiary of AREVA. It specializes in the exploration and mining of Canadian uranium deposits. Thus, people with diverse trade, technical and professional skills for their mine site in northern Saskatchewan are required. Employees are encouraged to improve their STEM skills by taking courses such as mechanical engineer technology, power engineering, heavy duty mechanics, and parts management. These courses are co-ordinated with, and run by, technical institutions such as SAIT, SIIT, and Northlands College (described in the section 'STEM-Related Technical or Professional Institutes/Colleges').

In addition to giving financial support for Saskatchewan STEM educational initiatives such as the Science Ambassador Program (described in the subsection 'School Outreach Projects'), three of its own STEM educational programs or projects stand out. The first is a pre-employment program for Indigenous northern Saskatchewan high school graduates who do not have the academic background needed for employment at a mine site. The program concentrates on increasing their literacy, mathematics and science skills so they can be competitive with their non-Indigenous counterparts in southern Saskatchewan. Partnerships with post-secondary technical institutes and colleges create classes which run for five to seven weeks and take place on the mine site so the course content is constantly related to uranium mining and processing. This content is taught in a need-to-know approach, and students' success is connected to work placement possibilities with AREVA Resources Canada. The courses are scheduled so students alternate one week at the mine site with one week at home. This continual contact with a student's family and community strengthens the student's resiliency and heightens their resolve to become a competitive high school graduate applying for STEM-related work.

The second program is for fully qualified high school graduates from northern Saskatchewan. It trains process mill operators on-site using AREVA trainers and contracted trainers where required. Between 12 and 24 participants are involved each year. After completing the two-month program, students with promise are offered an on-the-job paid training position with AREVA. This leads to basic certification, and with further work, possibly a '1A status' as a mill operator, which pays high wages.

A third project is an informal community-based outreach system. Indigenous Elders and school educators are encouraged to identify students with strong interests or high potential in science and mathematics. Mine site visits can be arranged where these students are given the chance to shadow various workers on the job to give the students an opportunity to create a strong image of themselves in any STEM-related career, but with AREVA if they wish. If students develop a strong picture of themselves in a STEM-related career, they become much more motivated to succeed at school because the concrete outcome of specific employment is far more effective than the alternative vague promise of 'doors will open for you if you graduate from high school'.

Generally when AREVA employees demonstrate specific capabilities, they can take advantage of opportunities to improve their education or expand their trade skills; for example, to work towards supervisory positions, or to become Chemistry Lab and Metallurgy Lab Technicians, etc. Participants would enter into a contract with AREVA in which these STEM programs would be paid for, and AREVA would provide the participants full time work during the summer breaks in these programs. At the end of the program, the participants would be required to work for AREVA based on the terms of the contract.

Some AREVA Indigenous workers from northern Saskatchewan are making six-figure salaries because they followed the STEM trajectory of a successful high school or pre-employment experience, followed by about six years with AREVA taking full advantage of educational opportunities and advancements. These people are role models for school-age Indigenous students, thereby helping to strengthen the quality of science and mathematics skills in northern schools.

Currently, there are plenty of opportunities in AREVA Resources Canada for qualified Indigenous graduates from high school, technical institutes, and universities. Priority is given to those who live in northern Saskatchewan.

Cameco (http://www.cameco.com/) is also one of the world's largest uranium producers. For the fourth consecutive time, Cameco has been named one of Canada's 'Top 100 Employers' in a national competition organized by Mediacorp Canada Inc. The annual competition recognizes Canadian companies and organizations that lead their industries in attracting and retaining employees. Cameco was also recently named a 'Top Employer for Young People,' a designation that is given to companies that excel at helping college and university graduates make the transition from school to work, and offer ongoing career development and advancement. For example, on-the-job trades apprenticeship programs are available for Cameco employees. In five years, a person can earn certification.

Numerous post-secondary scholarships offered by Cameco include the following:

- The Bernard Michel Scholarship provides support for a Saskatchewan Indigenous student entering their first year of study pursuing a B.Sc. degree in geology, toxicology, or chemistry; or a B.A. in geography land use and environmental studies. The $5,000 yearly award over four years also includes an opportunity for up to three summer work terms at Cameco's Saskatchewan operations.
- Cameco Scholarships in the Geological Sciences cover the costs for one year of study for students studying geological sciences at the University of Saskatchewan. Two scholarships are available for first and for second years of study. Recipients may also be offered summer employment at Cameco after their second and third years of study.
- Cameco Scholarship in Engineering recognizes academic achievement of students pursuing a B.Sc. in engineering with an interest in metallurgy and mineral processing in the mining industry. Two annual renewal awards of $5,000 each are offered, with a total potential of $10,000 a student.
- A Cameco Saskatchewan Institute of Applied Science and Technology (SIAST) Centennial Merit Scholarship of $2,500 annually promotes academic excellence for a Saskatchewan student in the power engineering program at SIAST.
- Cameco’s Northern Scholarship Program offers scholarships up to $7,500 for northern Saskatchewan students entering a university degree program and up to $5,000 for students entering trades or technical training at a recognized technical institute. Scholarships up to a total of $100,000 per annum are awarded under this program each year.
- Cameco Employees’ Dependent Children Scholarship is for students beginning their post-secondary studies in the fall or are already enrolled in a post-secondary program. Scholarships range up to $2,500.
- The Cameco Geological Technology Scholarship is available to a first-year and a second-year student enrolled in the geological technology program at Northern Alberta Institute of Technology for two annual awards of $5,000 each.
- The Cameco Mining and Mineral Process Engineering Scholarship encourages the pursuit of select engineering disciplines. Annually, up to six $5,000 scholarships are awarded to second year mining and mineral process engineering students at select post-secondary institutions.
- The Russell W. Thompkins Memorial Award in Mining Engineering is awarded on the basis of financial need and overall academic accomplishment to a student in the fourth year of a Mining Engineering program. Cameco provides funding to support one scholar per academic year.

In addition, Cameco established a ‘Math & Science Bursary Program’ to help First Nations, Métis, and northern students access up to six on-line mathematics and/or science classes (at $500/class) at the Credenda Virtual High School, administered out of Prince Albert, Saskatchewan. This bursary recognizes the northern Saskatchewan reality of students who are not able to access local, quality, mathematics and science high school classes that are needed to enter university programs directly from high school.

For Indigenous students in elementary and high schools, Cameco has helped enhance interest, knowledge, and skills in STEM by funding the Cameco Access Program for Engineering and Science (CAPES), administered at arms length by a group of university engineering and science faculty. This funding has supported many local educational initiatives in northern Saskatchewan over the years, including the project ‘Rekindling Traditions’ (Aikenhead, 2000, 2001) that created teaching units which served as a template for integrating science content into local Indigenous knowledge, all guided by Elders. Two major outreach projects currently sponsored in part by Cameco are the SCI-FI Science Camps program and the Science Ambassador Program (described in the subsection ‘School Outreach Projects’).

Through scholarships, trades’ apprenticeship programs, summer employment programs, bursaries, and a wide array of sponsorships, Cameco is a corporate model for increasing STEM capabilities among Indigenous citizens and for helping them access STEM labour markets.

Conclusion/summary

Like the majority of non-Indigenous Canadians, Indigenous people in Saskatchewan hold diverse views towards STEM. One pervasive view in Canada, however, is equating science with technological advances and economic development; in other words, science’s utilitarian function. For some Indigenous citizens, however, this utilitarian viewpoint can connect science unfavourably with the military hardware instrumental in colonizing Indigenous peoples. On the other hand, Indigenous communities that are becoming economically successful do favourably view STEM as a support to their progress (see examples in the subsection ‘Economic Context’).

In the context of education, a holistic viewpoint dominates an Indigenous perspective, which does not normally compartmentalize STEM courses from other subjects. Thus, attention tends to be given to a school’s overall learning environment rather than to the science classroom’s learning environment (described in the section ‘School Science’). More important, however, is the fact that many Indigenous people deeply and emotionally associate schools (and hence STEM courses) with the viciously oppressive residential school regime instituted by the federal government and run by various Christian religious organizations (see ‘Political Climate/Context’). For these people, STEM education is perceived as a neo-colonial force. In fairly large numbers, Indigenous parents’ negative reaction to schools can be so strong that they refuse to enter their child’s school building. This was evident, for example, when science teachers assessed the impact of ‘Rekindling Traditions,’ a project that promoted an Indigenous perspective on culturally responsive science teaching in northern Saskatchewan (Aikenhead, 2000, 2001). Teachers gauged the success of the project, in part, by the number of Indigenous parents who entered the local school for the very first time. They came to see for themselves the good things that they had heard were happening in their child’s science classroom.

At the same time, all Indigenous parents and communities want their children to succeed in the ‘new buffalo’ – getting an education (see ‘Economic Context’) – but not at the expense of losing their Indigenous identities. Students should not have to set aside or devalue their cultural knowledge in order to achieve in school science and mathematics. As described in the subsection ‘Successful Indigenous STEM Graduates,’ Hogue’s (2011) research into the lives of these graduates testifies to the importance of parental support. It is at the core of students’ resilience. On reserves located near Saskatchewan towns, Indigenous parents are often divided on whether to enrol their children at the federal on-reserve school or at the provincial school in town. In summary, views towards education are both ambivalent and diverse, as are views towards STEM.

The impetus in the 1970s to establish Indigenous teacher education programs, certified with the same authority as non-Indigenous (mainstream) programs, came from Indigenous communities. It was important to them to control their children's education, and for that to happen they needed Indigenous teachers. ITEP, SUNTEP, and NORTEP (described in 'STEM-Related Technical and Professional Institutes/Colleges') have been responsible for graduating many Indigenous teachers for on-reserve and off-reserve schools, although the number of STEM Indigenous teachers has been relatively small. In short, the new buffalo is a high priority in Indigenous communities, which holds promise for Indigenous control over their on-reserve education. STEM is a recognized part of the new buffalo.

One example of attention being given to STEM is the large investment made by Saskatchewan's First Nations political organization, the Federation of Saskatchewan Indian Nations (FSIN), to increase Indigenous students' STEM capabilities. Four years ago the FSIN created an annual province-wide science fair for on-reserve students in Grades 6-12, which features Indigenous knowledge projects and Eurocentric science projects. There are two completely different rubrics for judging the two types of projects (Aikenhead & Michell, 2011).The science fair is held for two days each March and is mostly paid for by the FSIN. It has already become a tradition, animated yearly by the curiosity and the hard work that students put into their projects. For many years, the FSIN has sponsored science camps held on reserves during the summer months.

The FSIN has been seriously searching for ways to increase students' scores on mathematics assessments. As suggested in the section 'School Mathematics,' improvements rely on culturally appropriate measures such as creating a vision for 'math hunters' (or warriors) in the new buffalo. But one cannot ignore the reality that, on reserves, low teacher wages and a lack of teacher tenure usually result in less qualified mathematics teachers being hired, the same people who probably only marginally passed university mathematics courses to begin with (see 'Political Climate/Context'). School financing will not by itself solve the problem of low mathematics scores, but there is definitely at this time in history a high direct correlation between federal funding and academic success. Unfortunately, current funding is being held hostage by the federal government in order to pressure the FSIN and other Indigenous organizations in Canada to accept the federal government's new education reform plan, which appears to continue Canada's colonization of First Nations peoples (Ibbitson, 2012). This standoff between the two parties is not encouraging for Indigenous students' STEM education in the short term.

In contrast with the general public's bias towards a utilitarian function of science, school science primarily deals with science's explanatory function – how does the universe work? The school's emphasis on describing and explaining natural phenomena can cause clashes between the cultures of STEM and the cultures of Indigenous students (see 'Culture and Linguistic contexts' and 'Research into Indigenous Students' University Experiences'). In the absence of culturally responsive science teaching, these clashes alienate many Indigenous students and cause their parents concern over continued assimilation initiated in residential schools.

> For some [reserve] chiefs, protecting Native control over education trumps all other considerations. The legacy of the residential schools debacle, and an ingrained

> suspicion of Western education as a tool of assimilation, has left them determined to keep on-reserve education in the hands of the reserve leadership. (Ibbitson, 2012).

As a result, attitudes towards STEM can be tied into attitudes towards residential schooling.

The success of programs designed to enhance STEM capabilities among Indigenous students at all levels of education relies *first and foremost* on policy makers, professors and teachers understanding that science and technology are anchored in a Euro-American culture, although they are open to people of all cultures as long as people follow the Eurocentric cultural norms of the paradigm in which they wish to participate. In short, STEM is a cultural entity itself. STEM and Indigenous knowledge share this common attribute, among others, as well as having distinctly different attributes (Aikenhead & Michell, 2011, Ch. 7). The stance that STEM is culture-free inhibits or excludes most Indigenous students from fully participating in STEM programs. Thus, this culture-free stance is an example of neo-colonialism at work. STEM does not compete with Indigenous knowledge; the two knowledge systems co-exist. *Their co-existence defines a level playing field for the participation of Indigenous students in STEM education at all levels*. This is fundamental to all culturally appropriate solutions for increasing STEM capabilities among Indigenous students.

A second foundation to the success of programs designed to build STEM capacity is the fact that culturally appropriate strategies are context dependent. Important contexts include: primary school, elementary school, high school, post-secondary education, and the labour market; as well as other contexts such as on-reserve and urban. What is culturally appropriate in one context, may not be in another context. For primary education, the focus is usually on cultural identity in terms of home language, customs, and students' experiences of success at school. For elementary and high schools, the focus is on all six aspects of culturally responsive science and mathematics teaching (see the sections 'School Science' and 'School Mathematics'). This includes the assumption that students will learn to *understand* how scientists think, behave, and believe without being expected to think, behave, and believe that way themselves. For post-secondary education, the focus is on ways of supporting Indigenous students in their pre-enrolment, their academic transition, their survival, and their savvy at knowing how the institution works.

Third, based on STEM educational research that has examined universities, the following conclusion can be made. Indigenous organizations and students are not asking STEM departments to include Indigenous knowledge or perspectives in the STEM curricula. But they are asking that their cultural identity be respected so that students experience a modicum of cross-culture dialogue between themselves and significant instructors in the cultures of STEM; in other words, the involvement of students and instructors in what Hogue (2011) called 'life-space' participation that helps Indigenous students become 'cultural oscillators' between their Indigenous culture and the culture of the STEM discipline being studied (see the subsection 'Successful Indigenous STEM Graduates').

Fourth, STEM departments, the designers and suppliers of programs to enhance STEM capabilities among both Indigenous and non-Indigenous students, should *not* possess an institutional culture of entitlement that systemically discriminates against and alienates historically marginalized groups of students. STEM departments should instead develop a culture of responsibility to attract and retain them – a cultural transformation towards acceptance of diversity within a STEM discipline (see ‘Research into Indigenous Students’ University Experiences’). Such cultural transformations at the university level will influence future science teachers who will then reproduce in their own science classrooms the department’s culture of responsibility and respect towards Indigenous students, thereby augmenting culturally responsive science teaching at the school level. A positive cyclic pattern of encouraging Indigenous students’ participation in post-secondary STEM programs will ensue. Surely in Canada’s era of reconciliation, this is not too much to expect of university STEM departments.

Fifth, because university academics are rightly respected for their critical-thinking capabilities, here are three key critical-thinking questions and a fourth ethical/moral question for STEM departments to address, with collaborative assistance from other university departments:

1. How can one explain the existence of the current practice that marginalizes Indigenous students in STEM courses and programs?
2. What knowledge counts as truth in this practice?
3. What enables the current practice to continue?

These questions frame a ‘critical stance’ (see subsection ‘Culturally Valid Student Assessment’), for which an ethical/moral imperative follows:

4. What is our department going to do, in the short-term and long-term, to ameliorate and eliminate the marginalization of Indigenous students who desire to succeed in our STEM courses and programs?

Inaction represents neo-colonialism at work.

Lastly, STEM employers (companies, institutions, agencies, etc.) that have policies and projects that both attract and retain Indigenous employees contribute greatly to increasing STEM capabilities among Indigenous people, as illustrated in the subsection ‘Two Mining Companies.’ The positive economic benefits for Saskatchewan and Canada are both significant and certain (see ‘Economic Context’). Government and corporate sectors now realize the wealth of Indigenous talent that has not been fully tapped. The efforts of government and corporate sectors, however, depend on every other stakeholder group enacting ways to enhance Indigenous students’ capacity in STEM, especially university STEM departments. A holistic systems-like approach holds greatest promise for success.

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APPENDIX

Recurrent Learning Strengths

Contrary to popular belief, there is little evidence that a stereotype ‘learning style’ for Indigenous students exists. Instead, evidence points to ‘*recurrent learning strengths’* (Hughes, More, & Williams, 2004; Alaska Native Science Commission, 2009) that tend to be found among Indigenous students. These strengths include:

1. holistic more than analytic
2. visual more than verbal
3. oral more than written
4. practical more than theoretical
5. reflective more than trial-and-error
6. contextual more than decontextual
7. personally relational more than an impersonal acquisition of isolated facts and algorithms
8. experiential more than passive
9. oriented to storytelling sessions more than didactic sessions, and
10. taking time to reflect more than quickly coming to an answer.

These recurrent learning strengths are evident in non-Indigenous students to varying degrees, as well. This list was modified from Aikenhead and Michell (2011, p. 131).