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ARTICLE

Treating Water:
Engineering and the Denial of Indigenous Water Rights

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In 2011, the Department of Aboriginal Affairs and Northern Development Canada released the National Assessment of First Nations Water and Wastewater Systems as prepared by Neegan Burnside Ltd. This assessment has been largely used by government, media, and Indigenous groups to point to the decrepit state of water and wastewater systems on First Nations reserves across the country, and to advance Senate Government Bill S-8 that seeks to improve conditions in these communities. In this article, I provide a critique of the National Assessment to outline its underlying assimilationist ideology and to demonstrate how technical engineering documents can have political implications. Power is wielded by technocratic discourses like engineering and, in this case, respect for Indigenous rights and sovereignty are at stake when so-called “objective” practices reflect institutional power.

KEYWORDS: First Nations, Canada, water, water rights, wastewater, engineering

HEADWATERS

Roxane and I have been given the value of Wisdom. We have been asked to synthesize a statement relating Wisdom to water. We are drafting part of a manifesto around the seven values (Courage, Respect, Humility, Truth, Honesty, Love, and Wisdom). Our statement will be combined with the preceding six, drafted by other pairings, to form the manifesto. This is part of a Waterlution workshop called “Our Water is Our Life: A dialogue and action weekend to look at the future of water for Aboriginal communities.” As a settler water resources engineering graduate student conducting research with a First Nations community, this event interested me.

Roxane introduces herself: she is a Blackfoot woman and Masters in Education. I introduce myself. We don’t really know how to begin addressing Wisdom, so Roxane shares a story of a near-drowning experience she had as a child. I also have a near-drowning story from childhood. We decide that this shared experience may be a good place to elaborate and while I’m still trying to think about how these experiences could possibly relate to wisdom, Roxane offers a quick explanation: water has wisdom and it imparts wisdom to us as we interact with it. Through her near-drowning experience, water shared its wisdom with Roxane and she became wiser for it.

I feel a little taken aback by this. Water doesn’t have wisdom. Surely one can become wiser by interacting with water, but water is not deliberately, consciously teaching us. Water’s

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1 Waterlution is a registered non-profit corporation that promotes awareness and provides opportunities for collaborative, long-term, and inclusive water management.
consciousness had been mentioned in the workshop the day previous, along with a story of how praying for water can ensure clean, healthy water. Coming from the Western tradition, I’m not familiar with this perspective but I do want to be sensitive to it, so I decide to explore Roxane’s analysis a bit in the hope of at least coming to understand it better.

I ask Roxane if she believes that praying for water makes it or keeps it healthy. She says that she does. I definitely don’t understand this. How could praying possibly impact water quality? I tell Roxane that it’s impossible for me to think of water as being conscious or that by praying for water, that water can be fundamentally changed.

Contemporary Western thinkers have considered similar beliefs. Actor–network theory, for example, attempts to decenter humans in technoscience and consider the agency of non-humans (Latour, 1987). Using such a framework can reveal how non-human entities (water, microorganisms, electricity, etc.) behave as agents, acting and reacting in their worlds. Certainly this school of thought could provide some insight on how Western philosophy—and my perspective—could theorize non-human experience. I hesitate to use this framework, however, when addressing an Indigenous person’s understanding of an Indigenous issue. Zoe Todd (2014), a Mètis scholar, explains some of the problems in this Western approach (along with further resources). Vanessa Watts (2013), Mohawk and Anishnaabe, picks up a critique of Latour’s work specifically and reveals some fundamental distinctions between Actor–network theory and Indigenous ontologies. Sarah Hunt (2014), a Kwakwaka’wakw scholar, further demonstrates ontological differences between Indigenous and Western philosophies. So back to Roxane.

After some more conversation and patience on the part of Roxane, I consider: a water user, someone who is consuming water, would probably change their behaviour if they believed that water was conscious or if they prayed before using it. I am reminded of a talk by Winona LaDuke, an Anishinaabe author and activist, who proclaimed, when discussing wastewater, how can water be waste!? If Western society viewed water as a conscious entity, or something worthy of more respect, a lot of water use behaviours would change, like using it for dilution or as a waste transport. It follows that one would also be more conservative with water use. If there are concerns about water scarcity, wouldn’t it be much simpler if water use were a less ubiquitous activity, one that involved respect? Folks would conserve more water. There would be fewer issues with water quality as waste management practices would require other solutions.

I try to relate these ideas to Roxane. I can explain the value in treating water as though it were conscious, an entity worthy of respect. I don’t see it as conscious myself at this point, but I try to rationalize the utility of thinking in this way. I ask Roxane if water’s consciousness can be understood as a resource management tool, if these ideas agree, if we are talking about the same thing. She says we are talking about the same thing. While I am still grappling with what it means to think about water as conscious, I can at least accept it as part of Roxane’s world and move on with the exercise. We write our statement on Wisdom.

**SOURCE WATERS**

This story is one of my first encounters with a directly conflicting worldview in my field of study. And while at the time I was still rationalizing what Roxane had said to mean something other than what she had actually said—water is conscious, praying for water is good, water is wise, water teaches us—it was an important step for me in better understanding my worldview and how it has been shaped by (Western) engineering discourse. Since the time of this workshop I’ve been curious about ways in which engineering epistemology disagrees with Indigenous epistemologies and if this could be related to the “infrastructure crisis” plaguing First Nations across Canada.
Knowledge, in Western academic thought, is inherently political and, as a result, can be oppressive (Potts & Brown, 2005, p. 261). I wonder, then, about the knowledge and thus political ideologies served by engineering as a discipline that espouses objectivity and disinterest (Leydens, Lucena, & Schneider, 2012, p. 71). In other words, what knowledges are subjugated by privileging an engineer’s approach to a problem over another’s? Foucault explains how criticism can reveal these subjugated knowledges that have been hidden or masked by dominant ones (1980, p. 82). I am interested in applying criticism to engineering as a dominant form of knowledge in Western culture.

In Winona LaDuke’s (1999) work, All Our Relations: Native Struggles for Land and Life, she touches on this apparent epistemological conflict between the technological (Western knowledges) and the spiritual (Indigenous knowledges):

The choice between the technological and the spiritual will be based on both collective and individual decisions, both simple and complex. For just as life itself is a complex web of relationships and organisms, so is the fabric of a community and a culture that chooses its future. Either way, according to Indigenous worldviews, there is no easy fix, no technological miracle. (p. 200)

In the article that follows, I provide a close-reading analysis of the National Assessment of First Nations Water and Wastewater Systems: National Roll-Up Report (hereinafter referred to as the National Assessment) and its explanatory materials to explore how a technical or objective approach to assessing/improving quality of water—and thus, life—on-reserve serves to epistemologically limit and control Indigenous rights and sovereignty. First, I contextualize the National Assessment and its significance as source material. Second, I analyze how the engineering and risk frameworks of the National Assessment describe water systems and the consequent limitations. Third, I elucidate how the National Assessment characterizes water and wastewater treatment plant operators as the site for risk, control, and legislation. Fourth, I demonstrate how the omission of (First Nations) people and governments from the National Assessment posits poor (waste)water servicing as a technical problem from which Indigenous communities are removed. Last, I restate the National Assessment’s problematic colonial narrative and conclude by reflecting on how my perspective has changed throughout my studies and since first drafting this article, emphasizing the need for community-based decision making.

In 2009, the Department of Aboriginal Affairs and Northern Development Canada (AANDC)2 retained Aboriginal majority-owned engineering consulting firm Neegan Burnside Ltd. to conduct the first cross-Canada evaluation of First Nations public and private water infrastructure. Two years later, on July 14, 2011, the National Assessment was released. The results were not promising. Hailed as “the largest and most rigorous assessment of its kind ever conducted in Canada” (AANDC, 2011d), this document classified 39 per cent of First Nations water systems as high overall risk of providing unsafe drinking water and 34 per cent as medium overall risk (Neegan Burnside Ltd., 2011, p. 16)—the implication being that improvements are necessary at an estimated cost of $1.08 billion.

The day of the National Assessment’s release, the Assembly of First Nations (AFN) responded, citing some of its results and the urgent need to improve water and wastewater systems (AFN, 2011). The House debate of Bill S-8 or the Safe Drinking Water for First Nations Act—which began less than two years later on November 1st, 2012—opened with a statement citing results of the National Assessment (Open Parliament, 2014). Members of Parliament continued to cite the National Assessment results throughout Bill S-8’s debate until it received Royal Assent in June 2013. News

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2 Then known as Indian and Northern Affairs Canada (INAC).
articles on water problems in First Nations communities have cited the *National Assessment* since its release and continue to do so. These actions point to the significance of this document and the relevance of its critique.

The analysis I present will draw primarily from the *National Roll-up Report* but as we are warned on the AANDC (2012) *National Assessment* webpage, “[t]he National Assessment results provide a substantial amount of information, much of which is fairly complicated and technical in nature. To help clarify the results and what they mean to First Nations, the Department has developed a series of informative fact sheets.” Thus, the various *Fact Sheets* and other documents that accompany the report found on the AANDC website will provide further material for analysis. These documents include:

- *Department’s Response to the National Assessment of First Nations Water and Wastewater Systems (Department’s Response)* (AANDC, 2011a),
- *Fact Sheet – Risk Assessment of Water and Wastewater Systems in First Nations Communities (Risk Fact Sheet)* (AANDC, 2011b),
- *Fact Sheet – The Results of the National Assessment of First Nations Water and Wastewater Systems (Results Fact Sheet)* (AANDC, 2011c),
- *Fact Sheet – Understanding the Results of the National Assessment (Understanding Fact Sheet)* (AANDC, 2011d), and
- *Chronology – Water (AANDC, 2013)*

My critique shares much in structure with some of Michael Mascarenhas’s arguments presented in his work, *Where the Waters Divide: Neoliberalism, White Privilege, and Environmental Racism in Canada* (2012), which I use to support my analysis. I also draw on Ulrich Beck’s *Risk Society* (1992) to underscore the social construction and formation of risk measurement, in addition to Donna Haraway’s “Situated Knowledges: The Science Question in Feminism and Privilege of Partial Perspective” (1988) and John Law’s *Aircraft Stories: Decentering the Object in Technoscience* (2002) to critique technoscientific and engineering methodologies. Let’s begin.

**WATER SYSTEMS**

It is apparent how the assessment process itself—the federal government entering First Nations communities to evaluate their water systems and wastewater systems—is a paternalistic exercise, disrespectful of First Nations sovereignty to choose to evaluate their own systems in their own ways. But within the *National Assessment* and accompanying materials are some more insidious modes of control.

One example is how risks of small water systems are compared to those of large systems, “[i]t was generally observed that the simpler the facility the more likely the facility was to have medium or high overall risk [...]. The simpler and small systems are often riskier as they are more likely to lack suitable treatment resources” (Neegan Burnside Ltd., 2011, p. 23). It is explained that risk increases as system size decreases and why a simpler, smaller system would be riskier: insufficient resources.

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3 I focus on the *National Roll-Up Report* instead of any of the *Regional Roll-Up Reports* because the results of the *National Assessment* as a whole were taken as evidence for the dire state of (waste)water servicing on First Nations reserves and as justification for subsequent legislation (Bill S-8). Plus, the more specific regional reports use the same methodology and communicate the same findings as the national one, simply on a regional scale with more discrete analysis. To my knowledge, the regional reports have not been used to advance legislation nor have they been cited as ubiquitously as the *National Assessment*.  

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Data presented in “Table 3.8 – Summary of Overall Risk Levels by Treatment Classification – Water”, which follows (see Figure 1), shows this relationship numerically between size (increasing “Level” number denotes increasing size) and risk.

![Table 3.8 - Summary of Overall Risk Levels by Treatment Classification - Water](image)

Figure 1. Screen Capture of Table 3.8 (Source: Neegan Burnside Ltd., 2011, p. 23)

The paragraph that follows in the National Assessment presents us with a similar comparison but for wastewater systems: “For wastewater treatment systems, it appears that a higher plant classification [a higher population served] is positively correlated with the incidence of a facility having a medium or high overall risk. MTA [Municipal Type Agreement] systems are the most likely to be low risk” (Neegan Burnside Ltd., 2011, p. 23). Here, no explanation is provided to clarify why this is the case, as was done for water systems before (lack of resources). There is no rationale presented to justify why the relationship between system size and system risk for wastewater systems is opposite of that for water systems. Surely small wastewater treatment systems lack resources to a similar degree as small water treatment systems. It seems odd then to provide a lack of resources as an explanation for water system risk without addressing how it affects wastewater system risk.

How this gap, or missing interpretation, is further communicated in the AANDC Understanding Fact Sheet is significant: “[t]he majority of high risk systems serve a small population. Water systems in remote communities are 2.5 times more likely to be high risk than low risk” (2011d). Here the risk results from water systems are used to describe all systems (both water and wastewater) even though the correlation between risk and population served (size) for wastewater systems is the inverse. This statement is then supported by a zone (remoteness) analysis of risk taken from the National Assessment. 49% of Zone 4 (more remote) water systems are high risk and 19% of Zone 4 water systems are low risk (Neegan Burnside Ltd., 2011, p. 19). By using these two data sets together (the zone-risk relationships and the size-risk relationship), the Understanding Fact Sheet suggests that small, remote systems (both water and wastewater) are more likely to be high risk.

Highlighting this connection between remoteness or smallness and risk marginalizes some communities by defining them as the site of risk while freeing other (more urban, accessible) communities of that risk. Critiquing risk measurement, sociologist Ulrich Beck describes how one is “afflicted by risk” and as such, risk is “ascribed by civilization” (1992, p. 23). Therefore, this devaluing of remote lifestyle in the National Assessment reflects a colonial ideology in which urban lifestyles are privileged. As Beck explains, there are always winners and losers in risk definition (1992, p. 23). What are shown to be objectively less risky (and more affordable) in the National Assessment are systems serving large populations near municipalities. By positing a smaller community as a dangerous way to live, the National Assessment leads one to believe that large social organizations are ideal. The stereotypical traditional First Nations “tribe” is risky, and the colonial industrialized city is safe. How does this sort of valuing allow First Nations to exercise sovereignty when certain ways of life are deemed costly or risky?

The National Assessment itself draws attention to this unbalanced evaluation:
The risk evaluation system is currently not set up to evaluate certain situations such as the typical Municipal Type Agreement (MTA) system where the First Nation has an agreement with a nearby municipality to provide water or wastewater services, nor is it designed to assess the risk associated with communities that rely on individual servicing or houses with no servicing. (Neegan Burnside Ltd., 2011, p. 42)

Further, “[i]n general, it is assumed that MTA systems would have a lower overall risk than other systems because they operate in accordance with provincial legislation” (Neegan Burnside Ltd., 2011, p. 22). Again, there is a reason why a system shared with a municipality would have less risk, because “they operate in accordance with provincial legislation”, but the National Assessment says that the “evaluation system is currently not set up to evaluate […] the typical Municipal Type Agreement (MTA) system”. What value is there in reporting the results of an evaluation which is not designed to evaluate the subject of interest? (And why is compliance assumed for water services under provincial legislation?) This critique applies similarly to “communities that rely on individual servicing or houses with no servicing” (Neegan Burnside Ltd., 2011, p. 42) (small, remote systems), which the National Assessment says cannot be properly evaluated using the current system. The results of the National Assessment are used to conclude that small, remote systems are risky and systems with Municipal Type Agreements are less risky although the National Assessment itself says it cannot properly evaluate either.

Moreover, this need to analyze data in a manner that uncovers national trends betrays another cultural bias of the National Assessment, and technoscience discourses more broadly: that of narrative continuity. John Law mentions engineers, and engineering texts, specifically, as story tellers of technology that display a “tendency to perform singularity and the concomitant tendency to marginalize multiplicity” (2002, pg. 76). Law explains that this tendency results in a bias against discontinuity, multiplicity, and “that which cannot be assimilated” (2002, pg. 76). So, for example, even though the relationships between (waste)water system risk and size cannot be entirely accounted for given the presented data in the National Assessment, “if we [engineers] cannot assimilate something, trace lines of similarity, explication, then somehow or other we failed. Even if the events present themselves as discontinuous. Broke up. Or multiple” (Law, 2002, pg. 76). The remedies put forth for risky (waste)water systems (money, legislation, operator certification) rely on this narrative singularity, as I explain later.

Second, as the explanation from the National Assessment for the correlation between size and risk explains, “smaller systems are often riskier as they are more likely to lack suitable treatment resources” (Neegan Burnside Ltd., 2011, p. 23). While it is apparent that a smaller system lacks resources, this explanation helps reinforce a purpose of the National Assessment: to emphasize the technical nature of the problem. A smaller or more remote system is missing access to physical resources regardless of the less tangible resources that exist in operator experience and local knowledge, for example.

Michael Mascarenhas specifically argues “how local contextualized knowledge is subordinated by technical ‘credentialized’ expertise” in water treatment on-reserve (2012, p. 18). Mascarenhas explains that the “prevalence of expertise functions to reduce societal problems” (2012, p. 18) to technical ones, removing “issues of power and equity” (2012, p. 19). Similarly, Donna Haraway, discussing the “science question” in feminism, argues that science and Western objectivity seek omniscient power by distancing themselves (the knowing subject) from everything (1988, p. 581). Haraway sees situated knowledge as a sort of feminist objectivity, where observers are responsible for their observations (1988, p. 583) and their enabling practices (1988, p. 587). Certainly localized knowledge is responsible to its localized context, a point to which I will return in the next section.

Mascarenhas shows that by introducing the requirement for treatment plant operators to hold valid operator’s certificates in Ontario, the government effectively “rendered the majority of First
Nations operators in the province as unqualified to operate their drinking water systems” (2012, p. 126). This type of legislation accomplished a similar feat as the National Assessment: a problem is created through definition and the means for addressing the problem lie in the hands of those who defined it. Without cooperation across groups of stakeholders involved in risk measurement (an unfortunate condition of the National Assessment), risk determination distintegrates into what Beck calls “definitional struggles” (1992, p. 29). By conducting the National Assessment, the problem of 39 per cent of First Nations water systems being high overall risk has been defined, paralleling how operators were defined to be unqualified in Ontario. Nothing has actually resulted from the exercise other than demonstrating that quality of life on First Nations reserves is unsuitable. The public has been informed about the resultant high risk (waste)water systems in First Nations communities and, for fear of seeming irresponsible, First Nations are expected to go through the appropriate funding and administrative procedures to address these problems (Mascarenhas, 2012, p. 130). This process again fails to allow First Nations to self-govern but also perpetuates an “infrastructure gap” whereby First Nations communities are defined as having deficient infrastructure by comparing their living standards to those of other Canadians (Mascarenhas, 2012, p. 5). Measuring risk inherently creates a universal, utopic norm for comparison—and risks exist as deviations from this “true” norm (Beck, 1992, p. 28)—urban settler Canadian society, in this case. First Nations communities must then seek financial support to meet protocols that are subsequently amended to show how deficiencies remain (Mascarenhas, 2012, p. 101). The very notion of development to certain standards, protocols, or guidelines, as Mascarenhas shows, is part of the neoliberal myth of development (2012, p. 105): it provides not only the mechanism for “improvement”, but the goal of “improved”. Seen in this light, the National Assessment reinforces colonial, assimilationist ideology.

WATER OPERATORS

A series of recommendations can be found at the end of the National Assessment including the “establishment of a regulatory framework for water and wastewater systems [...] approvals, operator certification, [and] water quality testing” (Neegan Burnside Ltd., 2011, p. 45). This recommendation and the results of the National Assessment at large were used to promote Bill S-8 or the Safe Drinking Water for First Nations Act.4 Bill S-8 was introduced less than a year after the release of the National Assessment and after much controversy during Idle No More, the bill became law. Among other First Nations (waste)water related issues, Bill S-8 grants the ability of government to create regulations on:

(a) the training and certification of operators of drinking water systems and waste water systems;
(b) the protection of sources of drinking water from contamination;
(c) the location, design, construction, modifications, maintenance, operation and decommissioning of drinking water systems (Senate of Canada, 2012)

“Regulations made under [Bill S-8] prevail over any laws or by-laws made by a First Nation to the extent of any conflict or inconsistency between them, unless those regulations provide otherwise” (Senate of Canada, 2012). Bill S-8 also allows regulations to “incorporate by reference laws of a province”, pushing provincial laws onto First Nations. Despite assurances that “nothing in [Bill S-8] or the regulations is to be construed so as to abrogate or derogate from any existing Aboriginal or treaty rights [...] except to the extent necessary to ensure the safety of drinking water of First Nation lands” (Senate of Canada, 2012), the Canadian Bar Association found that the qualification of

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4 See Legislative Summary – Bill S-8: The Safe Drinking Water for First Nations Act, “1.9 National Assessment of First Nations Water and Wastewater Systems” (pp. 5–6) or visit the Open Parliament webpage for Bill S-8 (https://openparliament.ca/bills/41-1/S-8/?page=2) to read references to the National Assessment.
“except to the extent necessary” “an explicit abrogation or derogation of existing Aboriginal or treaty rights pursuant to section 35 of the *Constitution Act, 1982*” (Craft, 2013, p. 2). The significance of Bill S-8’s history is how its acceptance heavily relied on the results of the *National Assessment* and how these results were communicated further.

Specifically in the *Department’s Response*, we find the following: “Operation and Maintenance (O&M), operator qualification, and record keeping account for 60 per cent of the risk measured. This underscores the vital importance of having trained and certified operators for reducing risk and helping to ensure safe drinking water in First Nations communities” (AANDC, 2011a). Further, “design risk only accounts for 30 per cent of the risk identified in high risk systems” (AANDC, 2011a). These excerpts are significant because AANDC (2013) highlights these results in *Chronology – Water*:

July 14, 2011 Department releases independent National Assessment of First Nations Water and Wastewater systems. Report states the need for a water and wastewater regulatory regime and standards on-reserve. The [National] Assessment shows that the operation and maintenance, operator qualification, and record keeping account for 60 per cent of risk measured.

These were the only results of the *National Assessment* that are shared on *Chronology – Water*: the need for regulation (Bill S-8) and that operators/staff account for the majority of risk. The problem lies not only with the fact that these are the results highlighted by the Department, but that the calculation for “60 per cent of risk measured” is one entirely defined through the assessment process. Plus, it is used in an attempt to place the cause of risk squarely on those working in (waste)water treatment (mostly First Nations operators and administrative staff).

Reviewing the *Risk Fact Sheet*,

the overall system rank is calculated using a weighted value for each category as follows:

- water source and the wastewater effluent receiver (10 per cent)
- system’s design (30 per cent)
- operation and maintenance (30 per cent)
- the level of training and certification of its operator (20 per cent)
- reporting and record keeping (10 per cent). (AANDC, 2011b)

“Operation and maintenance (O&M), operator qualification, and record keeping account for 60 per cent of the risk measured” (2011a, AANDC) (quoted previously) because they are defined as accounting for that much risk in the calculation. The risk calculation defines operation and maintenance (30 per cent), operator qualification (20 per cent), record keeping (10 per cent) to account for a total of 60 per cent of risk measured ($30 + 10 + 20 = 60$). By saying that these criteria account for 60 per cent of the risk, the Department suggests that this is a result of the *National Assessment* rather than the methodology used in conducting the *National Assessment*. One could just as easily conclude that the system’s design, operation and maintenance, and water source account for 70 per cent of the risk measured and that operator qualification only accounts for 20 per cent of the risk identified in high risk systems, emphasizing an entirely different aspect of system risk.

The point here is that this particular interpretation of the risk assessment tool confirms its colonial bias. Beck identifies those scientific and legal professions and the mass media (like technical communications) that define risk as holding key social and political positions (1992, p. 23). Beck elaborates that since hazards escape direct human perception, they require “qualified expert judgement [...] to determine [them] objectively” (1992, p. 27). And since risk always uses an imaginary link between cause and effect, it is invisible; the implied causality is theoretical and thus, scientized (Beck, 1992, p. 28). In other words, the science of risk (understanding and evaluating an invisible force) is accessible only to experts and those experts are political agents. The tool itself—
through the “objective” scientific power imbued in it—reflects and thus serves a political end. Returning to the document, the presentation of risk weights in the Department’s Response suggests that these categories are the actual causes of risk. By saying “operation and maintenance, operator qualification, and record keeping account for 60 per cent of the risk measured”, it makes operators and administrative staff the cause of risk. While the statement is strictly true (those particular aspects do account for 60 per cent of risk), its use to underscore “the vital importance of having trained and certified operators for reducing risk” (AANDC, 2011a) places the duty of risk reduction on operators. Mascarenhas explains that by shifting a social problem to a technical one, the victim is blamed for being incompetent (2012, p. 72). The symptom of degraded water quality is addressed as the problem rather than the cause: unsustainable relationships with the environment (Mascarenhas, 2012, p. 97). This is clearly demonstrated in the Risk Fact Sheet where water source (the actual quality and quantity of raw water available) only accounts for 10 per cent of the total risk weight. Undrinkable water from the environment and the consequent need for treatment are givens in this scenario rather than consequences of colonization/pollution.

Regardless of how treatment plant operators are characterized in other documents, in the National Assessment, “Operator” is actually the lowest contributor (pre-weight calculation) for risk in (waste)water systems as shown in “Figure 3.4 – Water: Risk Profile Based on Risk Components by Region” (Neegan Burnside Ltd., 2011, p. 18) (see Figure 2) and “Figure 3.6 – Wastewater: Risk Profile Based on Risk Component by Region” (Neegan Burnside Ltd., 2011, p. 21) (see Figure 3). The data collected for the National Assessment says that: “design risk is approximately 5.3 and operator risk is the lowest at 2.6” (Neegan Burnside Ltd., 2011, p. 16). This stands in direct opposition to how the “Department’s Response” interprets the risk evaluation where operators were suggested as being the most significant contributors to risk.

Figure 3.4 - Water: Risk Profile Based on Risk Components by Region

Figure 2. Screen Capture of Figure 3.4 (Source: Neegan Burnside Ltd., 2011, p. 18)
Figure 3 Screen Capture of Figure 3.6 (Source: Neegan Burnside Ltd., 2011, p. 21)

If design risk and source water risk were emphasized over operator risk, blame for poor (waste)water servicing would be shifted to other actors in the system. The federal government would certainly appear more culpable for providing inadequate resources for the necessary design of (waste)water treatment technologies on-reserve, while provincial governments would be scrutinized for their insufficient effluent discharge regulations to ensure safe water downstream of municipalities, industrial sites, and agricultural lands. By shifting the focus, and thus blame, for poor (waste)water servicing towards operators and away from colonial institutions, treatment operation becomes the role in need of improvement and subsequent control while poor environmental water quality and deficient technological design are accepted as normal.

Emphasizing the need to improve (waste)water treatment plant operation provides additional concerns for First Nations communities. In Where the Waters Divide, Mascarenhas, when discussing treatment plant operator certification, points out that "First Nations fear that in recognizing these new technologies of [the Canadian federal] government they may further discredit their own oral tradition of mentorship" (2012, p. 129). Not only may the role of (certified treatment plant operator) expertise be in disagreement with First Nations cultures and epistemologies, but its very creation is the "government's response to delinquent investment in drinking water conditions in First Nations communities" (Mascarenhas, 2012, p. 127). Water has been defined as a "technical problem in need of expertise. [...] This translation of racial programs [...] into technical discourses has been a key strategy of neoliberal governments where substantive authority of expertise and market logics are enrolled into the apparatus of political rule" (Mascarenhas, 2012, p. 127).

If operator expertise is the legitimate concern of AANDC as a result of the National Assessment, surely local, contextualized, first-hand knowledge would be valued in contributing to expertise over, say, a certificate in water treatment plant operation. As Mascarenhas concludes from interviewing treatment plant operators:

> the daily operation of a First Nations' water treatment plant requires a level of sophistication and dedication that is simply unparalleled. First Nations operators not only require a well-developed understanding of their treatment facility, but also are knowledgeable about local land use practices that might adversely impact the quality of their water supply. (2012, p. 126)
What Haraway describes as the “god trick” of technoscience, the process of “seeing everything from nowhere” (1988, p. 581), is applied in this scenario where credentialization (“objective” knowledge) supersedes localization (“situated” knowledge). Law elaborates on his explanation of narrative bias in technoscience: that in “telling stories and making connections”, context “is desegregated and colonized” (2002, p. 78). Rather than considering the unique situations of (waste)water treatment in each First Nation, the questions become: How can this problem be understood simply? What trends exist nationally? The multiple contexts of what feasibly affect (waste)water systems on-reserve have been given a new form to address all systems simultaneously, one where the cause of risk (water operators) and its solution (certification) are singular.

The Department’s Response concludes by stating “[l]egislation will enable the Government of Canada to collaborate with First Nations and other stakeholders to develop a regulatory regime for on-reserve water and wastewater” and that the “Government of Canada is moving forward with water legislation” (AANDC, 2011a). We can only assume that this is referring to Bill S-8, which was introduced six months later. We have seen how the “regulatory regime” unfairly targets treatment plant operation as the site for control/risk to further credentialize the problem, diminishing the ability of First Nations to self-govern (in the eyes of the Federal Government), but also how the premise on which it relies, that treatment plant operators are a large contributor to risk, is a misinterpretation of the data collected. Mascarenhas elaborates:

> While many First Nations I interviewed were in favor of more stringent standards and agreed upon practices that protect their drinking water supply, most also felt that this heavy handed use of legislation was an effective means to limit First Nations participation in matters of public health, and provided a means for government to relocate the provision of drinking water expertise firmly in the private sector. (2012, pp. 126–127)

Certainly the retention of private engineering consulting firms to conduct and author the National Assessment with public dollars shows a flow of money to financially support private expertise, but when that same body further advises greater investment in (treatment plant operator) certification, the private sector is not only bolstered but First Nations are even further removed from participating in governing their water resources. This removal of First Nations peoples from a national discussion on water concerns facing them is literally expressed throughout the National Assessment in other ways.

**WATER USERS**

Operators, it would seem, are the only humans individualized in the National Assessment. Their individualization, however, is used primarily to assign responsibility for the riskiness of First Nations (waste)water systems in accompanying materials. Nowhere in the National Assessment are people who rely on these water and wastewater systems mentioned, let alone discussed. Divorcing humans from the topic of discussion is evident immediately upon viewing the cover page of the National Assessment: the humans in the photos on the cover have no faces (see Figure 4). They are dehumanized and unrecognizable.

Hard hats obscure all of the photographed persons’ facial features except for the scant jawline. Their faces tend to be oriented away from the camera. To be fair, the National Assessment is about water and wastewater systems and not the people who build them, maintain them, operate them, or use them, so it might be out of place to show images featuring humans over the systems. It is bizarre, however, that such a deliberate and conspicuous attempt has been made to remove a human presence from these stock photographs. The problem is not entirely that these sorts of images are being used by an engineering consulting firm for a client (AANDC, in this case). Rather, it
is that this technical document is the medium through which AANDC has decided to communicate the findings with the public and First Nations who must live with these problems. That this engineering report (documents which typically do not rely explicitly on political, cultural, historical, or social understandings) is the appropriate mechanism for disseminating this information further emphasizes how the problem has been translated into a technical concern. Plus, the images presume that water improvements solely involve hard hatted professionals—that is, engineers and construction workers—completing technical work. Women and Indigenous people are notably underrepresented in these lines of work and they are absent from the cover images. What does this say about who ought to be involved and which roles they play in improving risky (waste)water systems on-reserve?

The National Assessment also excludes water from the discussion. The study isn’t even about water and wastewater; it is about the systems that treat water and wastewater. By relying on this technical engineering approach that focuses on systems or infrastructure, both humans and water are removed from the discussion as though these systems exist independently of either humans or water. Focusing on the technoscientific system ((waste)water systems, in this case) changes the subjects of study (water, people, First Nations communities) into mere parts of a larger system, as explained by Law (2002, pg. 78), and allows the narrator to distribute roles among these parts. Throughout the National Assessment, the real concerns and justifications for conducting the assessment (poor water quality, health problems, decrepit infrastructure) are dissolved. They are now products or expressions of the system (Law, 2002, pg. 78) so that operation, maintenance, and record keeping are what matter. The roles within the system have been successfully narrated and distributed so that water and humans have no purpose, leaving the technical components with all of the focus and importance. This erasure is a recent shift in communicating First Nations water concerns from previous government documentation as discussed below.

Some striking comparisons can be made between the 2011 National Assessment and the 2003 National Assessment of Water and Wastewater Systems in First Nations Communities, which served a

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5 The 2003 National Assessment of Water and Wastewater Systems in First Nations Communities Summary Report was not mentioned previously as an accompanying document because it does not really accompany the 2011 National Assessment. I only happened upon it by looking through archived Indian and Northern Affairs Canada webpages. The 2011 National Assessment only references the 2003 National Assessment once,
similar purpose to the 2011 National Assessment about a decade earlier. First, the 2003 document is actually authored by Indian and Northern Affairs Canada. The 2011 National Assessment is a direct report from a consulting firm to Indian and Northern Affairs Canada.

Second, the third to last paragraph of the 2003 National Assessment reads:

Significant progress has been achieved in improving water quality in First Nation communities over the last 10 years. For example, in 1991, less than 80 percent of on-reserve houses had basic water and sewer services; in 2001, about 98 percent of on-reserve houses had water and 94 percent had sewer services. During this time First Nations have assumed a greater role in the management and delivery of services as part of their move toward self-government. (INAC, 2003, p. 26)

This excerpt reveals a reference to historical data for comparison—something sorely lacking in the 2011 National Assessment—but also contains the word “self-government”, a concept missing entirely from the 2011 National Assessment. I do not mean to suggest that the 2003 National Assessment is less paternalistic in what it was attempting to do, but it is a report that used consulting engineers to collect and interpret data that was able to address both historical changes (and improvements) to First Nations (waste)water systems and the reality of self-government for First Nations communities.

The 2003 National Assessment uses the word “Chief” four times, “council” eight times, and “band” four times. The 2011 National Assessment uses “Chief” zero times, “council” twice, and “band” once, despite the fact that the 2011 National Assessment is over twice the length of the 2003 National Assessment. Even if this difference or change is not significant enough to point to a deliberate shift in policy or thinking, it does show how a technical document from 2003 can remain technical while at least acknowledging the political institutions at play; “[i]t is quite common to think that the explanations of engineers are objective, scientific, one-dimensional, lacking in ambiguity, trope or metaphor” (Bucciarelli, 2003, p. 6). Too often engineers express “discomfort at the idea of engaging in activities that might have such an overtly ‘political’ stance” but express “no reservation about taking an equally political stance in supporting the engineering status quo” (Leydens, Lucena, & Schneider, 2012, p. 64). Engineering communications must strive to remain objective, neutral, and unbiased, as shown through the political omissions in the National Assessment. But, just because the political institutions involved in planning, execution, and reporting of the 2011 National Assessment are obscured, does not mean they do not exist.

When Beck addresses water pollution specifically, he criticizes the approach of exclusively chemical, biological, and technological understanding, saying that it reinforces the optimism or inevitability of industrialization and can transform into a “discussion of nature without people” (1992, p. 24). This approach not only perpetuates the norm of industrialization (risks are managed rather than avoided) but humans and humanity are excluded. To not inquire about significant cultural, social, and political factors involved in risk hides them from analysis; the social affliction becomes a biological one (Beck, 1992, pp. 25–26). So “what becomes clear in risk discussions are
the fissures and gaps between scientific and social rationality in dealing with the hazardous potential of civilization” (Beck, 1992, p. 30). These fissures between scientific and social rationality are performed in the National Assessment.

Chronology – Water provides another significant erasure. Canada officially endorsed the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) on April 19, 2010. “Article 32” outlines “the right to determine and develop priorities and strategies for the development or use of [Indigenous peoples'] […] resources” (United Nations, 2008, p. 12) and that

]states shall consult and cooperate in good faith with the [l]ndigenous peoples concerned through their own representative institutions in order to obtain their free and informed consent prior to the approval of any project affecting their lands or territories and other resources, particularly in connection with the development, utilization or exploitation of mineral, water or other resources. (United Nations, 2008, p. 12)

Considering that this declaration defines both water resources management as an Indigenous right and the necessary role that Indigenous peoples play in the approval of water projects, why does its endorsement not appear on the Chronology – Water AANDC webpage? Surely Canada endorsing this declaration is noteworthy enough to appear on the timeline documenting water developments with Indigenous peoples in Canada. This endorsement actually occurred while the National Assessment was being conducted yet no mention of the UNDRIP nor the Indigenous right to manage water resources appears. The administrative and technical aspects supersede the importance of a discussion on Indigenous rights and sovereignty.

END OF PIPE

These particularly colonial interpretations of data discussed on the AANDC website may not be entirely surprising given the Department’s history and mandate. However, engineering practice—despite being a profession that professes objectivity and neutrality and deliberately shies away from taking political positions—can still uphold dominant forms of knowledge through its technical documentation. In the case of the National Assessment, the denigration of non-professional expertise and authority reproduces Canada’s racial formations.

I have shown that this sort of documentation—particularly the form in which it is presented to the public—is in fact, not all that technical. The way in which the information is shared tries to comfortably hide it from scrutiny under the guise of technical expertise with the warning that “[t]he National Assessment results provide a substantial amount of information, much of which is fairly complicated and technical in nature” to dissuade alternative interpretations. Not only should the presentation and interpretation of the data collected be done in a way to promote public consumption, but readers should be encouraged to undertake this sort of examination lest we continue to believe these documents' myths of apoliticism.

The National Assessment of First Nations Water and Wastewater Systems, as a technical engineering report, reflects political ideologies. The National Assessment, in both its process and content, is consistent with current federal legislation and exercises of colonial authority. The practice of conducting an assessment of First Nations (waste)water systems shows no acknowledgement of First Nations autonomy in the management of their own water resources. Further, the National Assessment reinforces a system in which First Nations communities are defined to be risky via an external system to which they must appeal for funding to become less risky. Since funding is directed to where an identified problem exists, the ability for First Nations to even demonstrate self-governance of water resources is lost. Last, the reliance on a technical document to communicate the findings exploits indirect language and a lack of human presence to continue to address concerns for water and First Nations peoples without having to discuss either water or
First Nations peoples directly. This facilitates a national discussion, or lack of discussion rather, on the denial of Indigenous water rights and Indigenous governance of water resources.

**DOWNSTREAM**

Over a year after our first meeting, I see Roxane, this time at an evening event on campus celebrating Indigenous authors. We recognize each other, she introduces her daughters who don't seem too interested in making my acquaintance, and I sit with her family at the back of the lecture hall. We exchange a few whispered words during the readings but we sit in silence mostly, listening to the stories. I reflect on some questions I can ask her when the event has ended but before that can happen, Roxane stands up with her daughters and explains that they have to leave early. I try to reassure her (and myself) that I'm still considering our conversation from a year ago, reflecting on the things she had shared with me, and that we will discuss this another time. We hug goodbye and she tells me to send her an email.

Engineers pride themselves on their ability to "solve problems" using their knowledge of scientific laws and technological innovation to do so, without having to mess with politics. But which political goals can be served when certain problems arrive at the engineer's desktop predefined? Or what implications can arise from engineering work that goes critically unexamined? History, culture, and community can certainly complicate some problems, but in excluding relevant system components, in stripping context from reality, in reducing multiplicity to singularity, solutions will remain elusive. And maybe there is a role for engineers and engineering in addressing these types of problems. Maybe it's just not up to engineers to decide. There are others setting the dialogue.

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Why Don’t More American Indians Become Engineers in South Dakota?

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American Indians are among the most under-represented groups in the engineering profession in the United States. With increasing interest in diversity, educators and engineers seek to understand why. Often overlooked is simply asking enrolled tribal members of prime college age, “Why don’t more American Indians become engineers?” and “What would it take to attract more?” In this study, we asked these questions and invited commentary about what is needed to gain more engineers from the perspectives of enrolled tribal members from South Dakota, with some of the most poverty-stricken reservations in the nation. Overall, results indicated that the effects of poverty and the resulting survival mentality among American Indians divert attention from what are understood to be privileged pursuits such as engineering education. The study’s findings indicated American Indian interviewees perceived the need for consistent attention to the following issues: 1) amelioration of poverty; 2) better understanding of what engineering is and its tribal relevancy; 3) exposure to engineering with an American Indian cultural emphasis in K-12 schools; 4) presence of role-model engineers in their daily lives; 5) encouragement and support from their peers, families, teachers, Elders, and tribal governments to value science, technology, engineering, and mathematics (STEM) education, particularly engineering fields; and (6) the embedded perceptions of math as a barrier to engineering studies.

KEYWORDS: Native Americans, engineering education, inclusion, diversity, critical-design ethnography

INTRODUCTION

As a matter of diversity and social justice, in recent years there has been increasing interest in educational attainment and participation in science, technology, engineering, and math (STEM) fields among American Indians (Aikenhead, 2001; AISES, 2015; Aragon, 2002; Cahalan & Perna, 2015; Carnevale & Strohl, 2010; Demmert, 2006; Hansen, 2015; Straits et al., 2002). In this study, we seek insights into the questions, “Why don’t more American Indians study engineering and select engineering careers?” and “What would it take to attract more?” specifically among enrolled tribal members who consider South Dakota home.

US Census and American Indians

The 2010 United States Census (Norris et al., 2012) provides data for the self-identified “American Indian and Alaska Native (AIAN)” population, an official census category, although tribal governments do not necessarily agree with the statistics listed under that category. Of 308.7 million Americans, 5.2 million (1.5 percent) self-identified as AIANs. From 2000 to 2010, the AIAN population increased by 37.5 percent compared to 9.7 percent for the overall US population.
South Dakota’s Pine Ridge Reservation ranks second and Rosebud Reservation ranks seventh for places in the US with the largest numbers of AIANs. South Dakota ranks second in states in the nation in numbers of AIANs with 82,073, of whom 61,582 identify as “Sioux Tribal Grouping” (US Census Bureau, 2013a), descendants of traditional speakers of Lakota, Dakota, or Nakota: Oceti Sakowin (The Great Sioux Nation).

Held back in part by lack of attainment of bachelor’s degrees, American Indians are underrepresented in engineering careers in the United States. When compared with the overall US population, a greater percentage of AIANs graduate from high school (including GEDs), have “some college or associate’s degrees,” and have three years or more of college or graduate school (US Census Bureau, 2013a). In addition, at 4.9 percent in 2011, American Indians are over-represented in US undergraduate engineering program enrollment, based on their status as only 1.5 percent of the US population. Of that 4.9 percent, 78 percent were American Indian men (NSF, 2011). Despite being over-represented in undergraduate engineering program enrollment, American Indians are underrepresented among engineering program graduates. Consequently, since practicing engineers typically need bachelor’s degrees or better, American Indians often lack the educational credentials necessary to enter the profession (see Table 1).

| 2010 US Census Detail | AIAN Population | US Overall Population | Difference |
|-----------------------|-----------------|-----------------------|------------|
| High school diploma, includes equivalency | 28.6% | 27.8% | +0.8 |
| Some college or associate's degree | 36.0% | 29.2% | +6.8 |
| Females [having] “3 years and over enrolled in college or graduate school” | 31.1% | 26.3% | +4.8 |
| Males [having] “3 years and over enrolled in college or graduate school” | 25.4% | 19.5% | +5.9 |
| Bachelor’s degree | 11.6% | 18.4% | -6.8 |
| Graduate or professional degree | 6.5% | 11.2% | -4.7 |

**South Dakota Set Apart**

There is an old saying in Indian country: “When you visit one reservation, you have visited one reservation”—a warning against generalizing across reservations, since tribes are very diverse. With that in mind, we found that South Dakota’s reservations are sometimes set apart as places of great need. For example, New York Times op-ed columnist Nicholas Kristof referred to Pine Ridge Reservation in South Dakota as “Poverty’s Poster Child,” comparing the locale to Haiti in terms of living conditions and describing the place as follows:

This sprawling Pine Ridge Indian Reservation is a Connecticut-sized zone of prairie and poverty, where the have-nots are defined less by the money they lack than by suffocating hopelessness.

In the national number line of inequality, people here represent the “other 1 percent,” the bottom of the national heap.

Pine Ridge is a poster child of American poverty and of the failures of the reservation system for American Indians in the West. The latest [US] Census Bureau data show that Shannon County [renamed Oglala Lakota County] here had the lowest per capita income in the entire United States in 2010. Not far behind in that Census Bureau list of poorest counties are several found largely inside other Sioux reservations in South Dakota: Rosebud, Cheyenne River and Crow Creek. (Kristof, 2012)
The Annie E. Casey Foundation’s 2012 Policy Report spotlighted South Dakota by noting in their children’s index of well-being, designed to measure “the steepest barriers to success”:

> The score for American Indian children in South Dakota is the lowest of any group in any state on the index at 185. The range of scores for American Indian children—185 to 631—is the widest in the index. (Annie E. Casey Foundation, 2012, p. 14)

Another indicator of lack of well-being, suicide among young people, has long been a problem on Pine Ridge Reservation in South Dakota, where the rate may be among the highest in the world (Young, 2008). Most recently, from December 2014 to May 2015, there were nine suicides on Pine Ridge Reservation among the 12 – 24 age group (Bosman, 2015). A former school administrator on Pine Ridge Reservation described the situation in *The New York Times*:

> Ted Hamilton, the superintendent of the Red Cloud Indian School, a Jesuit school on the reservation, says suicide is an issue that schools grapple with constantly.

> “To be Lakota in this world is a challenge because they want to maintain their own culture, but they’re being told their culture is not successful,” Mr. Hamilton said. “Children on Indian reservations,” he added, “have extraordinary challenges: the legacy of oppression and forced removals, the lack of jobs and economic opportunity, and the high levels of drug and alcohol use around them.” (Bosman, 2015, n.p.)

Despite a reputation for extreme poverty, there are many places of hope on and near South Dakota’s reservations. Promoting STEM education and careers contributes to a sense of hope because it encourages self-reliance and nation-building on reservations as sovereign nations within the United States. Some places that specifically promote STEM include Red Cloud School and tribal college Oglala Lakota College on Pine Ridge Reservation, Sinte Gleska University on Rosebud Reservation, and Flandreau Indian School near the Flandreau Santee Sioux Reservation, among others. For example, the US National Science Foundation is currently funding a program to bring engineering education to American Indians in a collaboration known as Oglala Lakota College, South Dakota State University, South Dakota School of Mines and Technology Pre-Engineering Education Collaborative (OSSPEEC) (Boyer, n.d., ca. 2012 and 2015; Kant et al., 2014a and 2014b; Sawyer et al., 2014; Tinant et al., 2014).

Tribally-related schools that promote STEM education are important for reservations in building sovereignty and self-determination. Hannan LaGarry (referenced below as HEL), formerly head of the Science and Math Department at Oglala Lakota College on Pine Ridge Reservation, wrote about the establishment of their pre-engineering program, OSSPEEC, at this tribal college and its relationship to tribal sovereignty:

> For the first time, we [Oglala Lakota College] are producing students who can advise the State and Federal governments, and our students are becoming knowledgeable enough to oppose them with evidence-based research, when necessary to maintain tribal sovereignty (HEL).

> ... Now we [Oglala Lakota College] have people from within and outside the tribe who seek us out for expertise. Now we have people who come to the reservation who want to collaborate with us. We have so many, we cannot manage them all. Now we can pick and choose (HEL). (Tinant et al., 2014, p. 11)

**UNDERPINNINGS OF RESEARCH**

The current pilot study has roots in an on-going US National Science Foundation (NSF) funded project seeking to develop the OSSPEEC initiative. In this initiative, starting in 2011, co-authors Kant and Burckhard found that it was challenging to recruit AI pre-engineering students into OSSPEEC. Recently, in collaboration with co-authors Meyers and His Horse Is Thunder, they
conducted a literature review to answer the questions, "Why don't more American Indians become engineers in South Dakota" and "What would it take to attract more?" That literature review found numerous articles about American Indians in STEM education (Babco, 2005; Chen, 2009; Howard-Brown, 2012; National Center for Educational Statistics, 2008 and 2011; Pewewardy, 2002), but none addressed the specific questions of interest. This pilot study was designed to fill that gap in the literature.

The critical pedagogy movement and liberation theology of Paulo Freire, as expressed in his books, Pedagogy of the Oppressed and Education as the Practice of Freedom, provide normative underpinnings for this inquiry. The most powerful element of Freire's work is that liberation pedagogy must be understood and realized at the level of those involved. In this vein, our study and analysis do not simply follow an a priori, top-down, imposed approach. As Freire noted,

No pedagogy which is truly liberating can remain distant from the oppressed by treating them as unfortunates and by presenting for their emulation models from among the oppressors. The oppressed must be their own example in the struggle for their redemption.
(Freire, 1970, p. 54)

As a matter of diversity and social justice (Baillie et al., 2012), we asked American Indian student interviewees (referred to here as “AI students”) and non-AI student interviewees (“non-AI students”) to partner with us and to share their understandings about what has happened in their lives and what should happen in bringing engineering education to them in South Dakota.

**METHOD**

**Critical-Design Ethnography**

In line with Paulo Freire’s insights, we sought meaningful engagement with our research subjects as much as possible, where American Indians were allowed to seek their own answers in their own voices and to serve as their own examples (Freire, 1970). Aside from that emphasis and in terms of contemporary anthropological research design and strategies, our research is exploratory, similar to grounded theory that seeks descriptions that may lead to the evolution of meaningful theory and metrics and that may precede explanatory research (Bernard & Gravlee, 2014; Hammersley & Atkinson, 2007).

To pursue this exploratory approach, we conducted critical-design ethnography, where the objective was to determine how to better understand why more AI students do not pursue engineering educational credentials and careers, and how to encourage more to do so. The method is inductive, seeking patterns rather than testing hypotheses. “The process sits at the intersection of participatory action research, critical ethnography, and socially responsive instructional design” (Barab et al., 2004, p. 254). We applied collaborative, critical-design ethnography including semi-structured dialogic interviews with structured open-ended and select-a-response questions, resulting in both qualitative and quantitative data (Hammersley & Atkinson, 2007; Savin-Baden & Howell Major, 2013).

We engaged staff and students at the American Indian Education and Cultural Center at South Dakota State University (SDSU) to recruit undergraduate AI student interns to conduct interviews, a deliberate strategy that follows suit with participatory action research. In participatory action research the goal of ethnography is to empower and to build relationships with the research community.

This model, in turn, is also critical ethnography because it attempts to engage in social change by way of taking a critical stance, where the researchers (in this case, the AI student interns) become
the change agents who are collaborating with the community under study. In recruiting AI student interns to conduct the interviews with AI students, we were afforded change agents engaged in collaboratively developing structures intended to critique and support the transformation of the American Indian communities being studied. The roles of the AI student interns were as critical ethnographers and instructional designers. They were interested in research and development of designed structures that may facilitate learning and empowerment, as well as the relationship of a segment of South Dakota’s American Indians to engineering.

Interns received a week of training in ethnographic interviewing techniques and research instrument construction (a methods boot camp), which followed a discourse-centered approach (Farnell & Graham, 2000) conducted by SDSU anthropologist Richard T. Meyers (an enrolled member of the Oglala [Lakota] Sioux Tribe) and SDSU geographer and biologist Joanita M. Kant. Training included self-reflective journaling for AI student interns about being an American Indian in South Dakota, role-playing to test sample probes, and describing cultural norms in their respective communities within focus groups.

Project leaders and all student interns completed two weeks of training. In addition to the methods boot camp for interns, the first week included earning on-line training certificates in Protecting Human Subjects in Research from the National Institutes of Health (NIH, 2015). Interns and some project leaders also met with Norm Braaten, SDSU’s Research Compliance Coordinator, for a research ethics question-and-answer session. During the second week, interns participated in training around the question, “What is engineering?” with SDSU Professor of Civil Engineering Suzette R. Burckhard.

None of the AI student interns were engineering majors, since that candidate pool is very small. (Out of about 12,500 students at SDSU, only about 240 self-identify as American Indians, and very few of them major in engineering.) The AI student interns were enrolled tribal members in some of South Dakota’s Oceti Sakowin (Great Sioux Nation) tribes: Yankton Sioux, Cheyenne River, Oglala Lakota, and Standing Rock. Their majors included political science, counseling and human resource development, environmental science, interior design, and nursing. In addition, we recruited one non-AI intern, an engineering major, to conduct comparison interviews with non-AI students currently not majoring in engineering.

**Research Instrument**

All student interns helped to construct the research instrument that was used to conduct the interviews. All interviewees, both AI and non-AI students, considered South Dakota as “home,” and the study only included those of prime college age, from 18 through 30 years, with at least some education beyond high school (even as little as one class), all non-engineering majors. The reasoning for these selection criteria was to include those most likely to be in the post-secondary education system by age, and those who had shown at least some inclination to seek education after high school. We selected non-engineering majors because the topic is not “Why did you major in engineering?”—a question that is beyond the scope of this study. Rather, the questions we asked sought insights into why certain categories of people do not major in engineering and seek engineering careers, and how to attract more of them to the profession.

About half of the AI students in this study were enrolled in the Oglala [Lakota] Sioux Tribe with ties to the Pine Ridge Reservation, and over 90 percent of AI students in the study were enrolled in tribes comprising the Oceti Sakowin (Great Sioux Nation). Seven percent were enrolled in various non-Oceti Sakowin AIANs in South Dakota. We also interviewed a non-American Indian comparison group. We refer to American Indian interviewees as “American Indian (AI) students,” their parents as “AI parents,”...
non-American Indian interviewees as "non-AI students," and non-American Indian parents as "non-AI parents."

Having established a research instrument and the population characteristics for their interviewees, student interns used a “snowballing” technique (Bernard, 2014) to identify interview candidates. Snowballing entailed notifying friends and relatives that they were seeking interviewees; those, in turn, contacted others to enlist their participation. Using this technique, AI student interns independently recruited 107 AI students, and the non-AI student intern independently recruited 30 non-AI students. Snowballing has been shown to be effective in gaining participants among the state’s tightly knit tribal populations (Kant et al., 2015). From July 18 to September 11, 2015, the interns conducted and transcribed all interviews using the research instrument shown in Figure 1.

### Part 1.
1. Age?
2. Gender?
3. Where did you grow up?
4. Where do you consider home?
5. What is your tribal affiliation?
6. What was your experience like in school?
7. What’s your highest level of education?
8. What is your parents’ highest level of education?
9. What comes to mind when you think of engineering?
10. Have you had any exposure to engineering?
11. What was your experience with engineering?
12. Have you ever considered engineering as a field of study?
13. What might have encouraged you or your friends to study engineering or become an engineer?

Prompt: Engineering is the creative application of math and science to solve problems. Examples of engineers include mechanical, civil, electrical, and agricultural, to name a few.

### Part 2. Factors in Selection of Major

| On a scale of 1-5 how much influence did the following have on your field of study? | None | Little | Some | Substantial | Very Extensive |
|---|---|---|---|---|---|
| A Family | 1 | 2 | 3 | 4 | 5 |
| B School activities/classes | 1 | 2 | 3 | 4 | 5 |
| C Personal interest | 1 | 2 | 3 | 4 | 5 |
| D Activities/programs outside of school | 1 | 2 | 3 | 4 | 5 |
| E Other if applicable | 1 | 2 | 3 | 4 | 5 |

### Figure 1. Research instrument: Interview questions, Parts 1 and 2

### Coding the Data

After the manner of Strauss & Corbin (1990), Liamputtong & Ezzy (2005), Liamputtong (2007), and Dickson-Swift et al. (2007), we formed a plan to code the data. First, co-authors Kant and His Horse Is Thunder coded the interviews by repeatedly reading them to identify persistent themes. Recognizing that some words and phrases applied to more than one theme, they combined some themes while attempting to preserve the intent of the interviewees’ comments. Second, they color-coded words and phrases related to the themes. Third, they extracted percentages or generalizations from the coded data. Fourth, they selected individual quotations from AI student
interviews representing certain themes to convey deeper insight. Fifth, they contrasted the AI students’ responses with those of the non-AI students to provide some basis for comparison.

**Limitations of the Study**

The National Center for Educational Studies (2008) has noted that readers should use caution when generalizing about their data relating to American Indian studies for the reasons listed below. In like manner, we caution readers that, as in many larger studies of American Indians, our sample populations are small, reducing reliability of the data. Because of this, even large observed differences may not be statistically significant. In addition, self-identification of tribal affiliation may be unreliable. We provide only a sample of the range of the hundreds of variables that might be extracted from our data. Some comments by interviewees may fit well into more than one theme. The topics of interest represent complex relationships and many interactions that we only briefly explore. In addition, snowball sampling does not provide randomized study populations, but we found that it was the best way to recruit participants in significant numbers among South Dakota’s American Indian population with limited resources and funding for the research.

**RESULTS AND DISCUSSION**

This section summarizes and discusses the results of our interviews, organized according to our research questions.

**Study Population Demographics**

*What are your age, gender, hometown, and tribal affiliation? (Questions 1-5)*

Table 2 summarizes results from questions 1 through 5 in the research instrument including age, gender, hometown, and tribal affiliation. Although 76.6 percent of AI students indicated that their hometown is on an American Indian reservation in South Dakota, many others identified hometowns just outside reservation boundaries in South Dakota. Although interviewees reported enrollment in 14 tribes, the largest group, 52 percent, is from the Oglala Lakota Sioux Tribe (i.e., Pine Ridge Reservation), and the majority are from various tribes within the larger category, Oceti Sakowin (Great Sioux Nation). While there are 82,073 persons who identify as AIANs in South Dakota, over 20,000 identify as members of non-Sioux tribal affiliations (US Census Bureau, 2013). Thus, it is appropriate to have included other tribal groupings in our study, although South Dakota is historically thought of as the homelands of the Oceti Sakowin.

**Table 2. Study population demographics (American Indian students were enrolled in 14 tribes)**

| Study Population | Age Average | Age Range | Gender % | Hometown % | Tribal Affiliation % |
|------------------|-------------|-----------|----------|------------|---------------------|
| AI Students (109) | 22          | 17-30     | 51.4     | 46.8       | 1.8                 |
| Non-AI Students (30) | 20         | 18-29     | 50.0     | 50.0       | 0.0                 |


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School Experience

What Was Your Experience Like in School? (Question 6)

The following themes were most commonly reported by AI students regarding their experiences in school, in order of frequency:

1. Likes school, 46 percent
2. Difficulties with school, not academically or socially prepared, 24 percent
3. Negative view of school, 18 percent
4. Apathetic toward school, 17 percent

Sub-themes for school experience report by AI students included the following, in order of frequency (Question 6, continued):

- Poorly performing on-reservation schools and staff compared to off-reservation schools
- Stressful school and home-life
- Frequently moving
- Difficulty transitioning from the reservation to non-reservation
- Teenage angst and bullying
- Lack of encouragement
- Financial difficulties
- Responsibility for relatives

The differences between AI and non-AI students’ attitudes toward school are shown in Table 3. In addition, 10 percent of non-AI students (i.e., 3 of 30) reported financial concerns, and three percent (i.e., 1 of 30) made negative statements about personal well-being, such as items listed in the sub-themes category above.

Table 3. Comparison of AI student and non-AI student school attitudes

| Study Population          | Highest Ranking Statements about School Attitudes % |
|---------------------------|-----------------------------------------------------|
|                           | Likes | Does well and likes | Negative or apathetic view | Under-prepared academically or socially |
| AI Students (107)         | 46    | –                   | 17.5                        | 24                                      |
| Non-AI Students (30)      | –     | 93                  | 7 (but only in high school) | 3                                       |

Educational Attainment

What Is Your and Your Parents’ Highest Level of Educational Attainment? (Questions 7 and 8)

Table 4 summarizes results for educational attainment. AI parents occasionally did not graduate from high school, unlike non-AI parents. AI parents were much less likely to hold higher degrees than non-AI parents in every category except associate’s degrees. Only 5.5 percent of AI students’ fathers held bachelor’s degrees, compared to 46.7 percent of non-AI fathers. Fourteen percent of AI students did not know their father’s highest level of education or did not respond, which may have artificially reduced their fathers’ educational attainment scores. Non-AI students generally knew their parents’ highest level of education.

AI students’ mothers lagged behind non-AI mothers in educational attainment in every category except associate’s degrees. Across the entire study population, STEM majors were rarely reported, with the exception of medically related degrees.
Table 4. Study population and their parents’ educational attainment

| Study Population | Years Average | Range | STEM Major % | Highest Level of Earned Certificates and Degrees % |
|------------------|---------------|-------|--------------|--------------------------------------------------|
|                  |               |       | Certificate  | Associate | Bachelor | Master | Doctorate |
| AI Students      | 14.9          | 12.1-18 | 2.8         | 1.8       | 7.3      | 5.5    | 1.8       | 0        |
| AI Mothers       | 14.4          | 8-21   | 3.7         | 1.8       | 15.0     | 17.4   | 12.8      | 0.9      |
| AI Fathers       | 12.9          | 8-21   |             | 1.8       | 5.6      | 5.5    | 2.8       | 1.8      |
| Non-AI Students  | 14.0          | 13-16.1| 0           | 6.7       | 6.7      | 16.7   | 0         | 0        |
| Non-AI Mothers   | 15.3          | 12-18  | 0           | 13.3      | 6.7      | 30.0   | 20.0      | 3.3      |
| Non-AI Fathers   | 14.8          | 12-20  | 3.3         | 13.3      | 3.3      | 46.7   | 6.7       | 3.3      |

Experience with Engineering

What Comes to Mind When You Think of Engineering? (Question 9)

The most common themes for AI students were, in order of frequency: math, building and creating things, infrastructure and vehicles, and difficulty. Less common themes included: science, designing and inventing, types of engineering, working on things, and problem solving. Types of engineering listed included: mechanical, electrical, chemical, computer, bioengineering, medical, and environmental. Although most did not, one AI student gave a lengthy reply to this question:

[Engineering involves] tanks, trains, bridges, rockets, and those weird metal art shapes in front of public buildings. Anything big that has ever happened to humanity, kind of has to do with engineering—ships and planes, tanks and guns. Anything major that has happened, engineering was in its back pocket.

For the non-AI students, the most common themes were, in order of occurrence: math, building and designing, science, and smart. Less common themes included: blueprints, architecture, and problem solving.

Have You Had Any Exposure to Engineering? (Question 10)

Forty-eight percent of AI students responded yes, and 52 percent responded no. Non-AI students replied 60 percent yes and 40 percent no. Many of the exposures that both groups identified as engineering were not typically considered to be engineering activities, such as repairing cars. Many of those who responded that they had no exposure to engineering, later reported instances of exposure that they had not recognized to be engineering, such as Gear Up activities, indicating that many interviewees do not understand what constitutes engineering.

What Was Your Experience with Engineering? (Question 11)

Among AI-student respondents, two majored in engineering at some point, but one changed majors to music and the other only completed a short course as part of the military with no indication of intent to continue in engineering. AI students reported only one parent as a practicing engineer. The most frequent experience reported was knowing a friend or relative with some connection to engineering, followed by having had a summer experience through Gear-Up, and having participated in an event at SDSMT or Oglala Lakota College or other university. Infrequently listed experiences included American Indian Science and Engineering Society (AISES) events, the Army,

1 Gear Up is a US Department of Education program aimed at increasing enrollment in college and post-secondary educational programs among high-poverty populations. In South Dakota, the state’s Gear Up initiative focused specifically on American Indian populations.
on-line searches, some college courses, and high-school class visitors. It was rare that they reported no experience in response to this question. This disparity is explained in responses to Question 10, above.

One non-AI student reported having a father with an engineering degree, but went on to say that he now teaches high school. Non-AI students most often reported: knowing an engineer or knowing an engineering student, no experience, or having participated in some high-school or middle school activities. Less frequent replies were middle-school engineering camps, high-school competitions, and tours of SDSMT.

*Have You Ever Considered Engineering As a Field of Study? (Question 12)*

AI students replied 29 percent yes and 71 percent no. Results were nearly the same for the non-AI students at 30 percent yes and 70 percent no.

*What Might Have Encouraged You or Your Friends to Study Engineering? (Question 13)*

AI students reported the following (multiple responses were allowed):

- More information about engineering, 44 percent
- Exposure to engineering, 29 percent
- Want engineering programs, 28 percent
- Want more engineering curriculum and faculty support, 26 percent
- If liked math (i.e., see math as a barrier), 23 percent
- Need to know someone who is an engineer, 13 percent
- Encouragement, 11 percent
- Need for engineering to relate to community, 10 percent
- More confidence in their own capabilities, 7 percent

A few AI students reported exposure to engineering activities in middle and high school that were encouraging, especially through Gear-Up and Oglala Lakota College. Three examples of such comment follow:

I think that all of the cool experiments that were going on in Gear-Up encouraged a lot of the students to go into engineering. It was usually the males who were more excited about it. For me, I really enjoyed the chemical experiments. Those were pretty cool. I think that an after-school program that is a continual thing would help get males and females interested in it. Have an hour or two hour engineering program where you have the experiments, challenges, or contests to get people interested in it.

One time we had a blacksmithing class where we made our own things out of metal, we used the heat to bend the metal. In another class, each of us had a group where we participated in college students’ engineering assignments…. We helped the student with that. College students would also come in and present their experiments (robots, dry ice, and chemical reactions).

There was a science program at Little Wound where we would go to the Oglala Lakota College (OLC) and play with flight simulators. We would get into groups and build our own type of aircraft and would have to do it with under one million dollars. If it couldn't get from point A to point B then we would have to start over. I thought it was pretty cool.

Among AI students, one of the most pervasive comments was that they had a general lack of understanding of what is involved in becoming an engineer. For example, some AI students noted:

[N]ever have I ever given it a thought. It was never really an option in high school. I mean, you never did hear anyone talk about why we should go into engineering.
I don’t even know what they [engineers] do; so I would never just decide one day that I want to be an engineer.

No, I have never considered it because I have no idea what it is or what engineers do.

Generally, AI students reported that there is a need for consistent exposure to engineering studies and careers beginning as early as grade school and continuing through high school. Other engineering exposures listed include after-school programs, summer programs, workshops, and camps, as well as internships and apprenticeships at tribal colleges. AI students noted the importance of high-school engineering classes, renewed focus on math courses (especially those necessary for engineers), caring mentors and advisors, and extraordinary teachers.

AI students also recommend consistently presenting to K-12 students details about “the system”: types of engineering, engineering salaries, what engineers do on a daily basis, descriptions of high-school and college courses required to earn an engineering degree, how much education is necessary to become an engineer, how the college culture operates, and how engineering education might be funded. One AI student responded as follows.

Give students more information about it and about the opportunities. I would get graduates, who have a job in engineering to come in and express their experiences, whether they are native or non-native.... Students could get every little detail from dorm life to academics, summers, and how to pay for it. Let students know that there are different ways to accomplish those things, but how they persevered, without race being a part of it.

AI students reported the need for encouragement that they can achieve their educational goals, and the necessity of a strong work ethic. They indicated that educators should provide role models in reservation settings. They emphasized that information should be tailored to the individual student and related to helping a reservation community. Persistent themes include a desire to help others, especially their reservation communities through culturally relevant, creative, and interesting activities. AI students reported the need to understand the effects of engineering in various aspects of daily life.

AI students acknowledged the importance of financial support from tribal governments. They also recommended the inclusion of families in engineering-awareness-raising activities, since many students are “non-traditional” and some college students have infants and young children. They indicated the need to include parents, grandparents, teachers, Elders, and tribal governments, since their encouragement may be vital in making engineering education meaningful to American Indian community interests.

**Reflections on the Role of Poverty and Traditional Culture**

One important finding of this study is that AI students consistently reported that they failed to see how engineering could help reservation communities. The following are insightful comments from AI students, many of whom are caught up in poverty intertwined with their traditional culture. Their comments invite new interpretations of this century’s revived concept of the “culture of poverty” (Small et al., 2010). Far from blaming those in poverty for their situation, our findings here indicate that poverty and its resulting survival mentality divert attention from what are understood to be privileged pursuits, such as engineering education. Consideration of these comments helps to explain why, considering Maslow’s (1943) hierarchy of needs, becoming an engineer may not be a priority for many American Indians in South Dakota.
As with the rest of this study, AI student comments assert the importance of consistency in addressing barriers to engineering. AI students identified the following needs:

1) Amelioration of poverty
2) Understanding of what engineering is and its tribal relevancy
3) Exposure to engineering with cultural emphasis in K-12 schools
4) Presence of role-model engineers in their daily lives
5) Encouragement and support from their peers, families, teachers, Elders, and tribal governments to value STEM education, particularly engineering fields
6) Attention to embedded perceptions of math as barriers to engineering studies

Examples of barriers in the wake of poverty include these three comments by AI students:

Growing up in poverty you aren't expected to grow or further your education.

There aren't enough people talking about ways to pay for school.

I feel like the kids don't have the confidence to do it. They think, "Oh, I'm just going to go to tribal college because I can't make it out there financially." Let them know that they can do it, but that they will have to make that decision on their own.

While it is not typical to have both parents die young on South Dakota's reservations, one 21-year-old interviewee reported:

Right now, I am at [a tribal college] after being at [an out-of-state college] for two years... I like my classes... The reason I came back was because my mom died ... then my dad followed. I was left with my little sister and brother to look after. My parents were really proud of me when I went to college. We never had much money because they didn't go to school and get good jobs like some people's parents, but they did their best.

Examples of the need for understanding the tribal relevancy of engineering and other cultural gaps include these three comments by AI students:

Maybe if we weren't in so much hurt we would have time for important things like engineering. But you can't blame us for wanting to fix all the issues we face now.

A lot of people want to change the reservation so badly; so they do the things that would change it all. Do science and engineering have the ability to turn around the reservation as fast as a business or economics degrees? Everyone is living to survive and what that means is that a job is money, and a degree is one that will ease the poverty. That means people want to be nurses, politicians, and psychologists. So why would people worry about engineering?

It's pretty much a lack of representation of our ethnicity. One of my friends is pursuing a degree in engineering, but he does a lot for the Native American community in Rapid City. He's working with the Rapid City Police Department and Congress, and it has opened a lot of doors for him. It helps a lot seeing one of our own doing something in a specific field. If there were more people who did that around me [it would help in recruiting more native engineers]. Not a lot of people in my family are engineers. They are in construction and child care.

Aside from the cultural relevancy just described, AI students noted the need for exposure to engineering in elementary through high schools, as in these four comments:

It all starts with middle school and high school when the teachers start asking students what they want to pursue in life. Most kids say a doctor or lawyer. Giving them the idea of doing something other than that, in order to influence them in the science classes would help. There could be a curriculum that incorporates engineering as well.

Start young. Start encouraging kids in the eighth grade level because most kids go into high school not knowing what they want to be when they grow up... If you show them that they
can do something that they can be proud of, then maybe you can get more Native American students in the field of engineering.

All my friends are in college in everything but engineering… But it would have to take a lot to change their minds to become an engineer, let alone encourage them. It would have to start when we were freshmen in high school for us to be encouraged.

I think if we all knew that we could do it and have had the support to guide us along the way, it would have been possible [to become engineers]. At … [a reservation high school] they help you apply for college and get accepted, then kick you out the door and tell everyone that they have a 100 percent graduation rate and that all the graduates have plans for higher education. Then that’s it. No one wants to go the full way with people. Our parents would, but even they don’t know what engineering is or what it entails. So I would say the mentoring, that’s always important.

AI students also provided examples of the importance of having role-model engineers in their daily lives, as in these four comments:

In high school I took a lot of automotive courses and there were 23 guys in the class and maybe three girls. Promote the idea that it is okay to be interested in that kind of stuff, that it isn’t bizarre for girls to be interested.

When I was in school, engineering was one of my top choices, especially in grade school. I was always told I could be an engineer, but as I got older my mind changed. I didn’t know a lot of engineers when I was growing up. I was more around my family being in the hospital, so instead of being an engineer, I thought I would be something else.

A huge part of it is that we don’t have a lot of engineers on the reservation. There are only a few of them and most of the stuff that we have done here [on the reservation] is done by independent contractors outside of the reservation.

In addition, AI students spoke of the need for encouragement from peers, families, teachers, Elders, and tribal governments in promoting STEM education, particularly engineering:

I don’t think a lot of my friends know about engineering. It would have taken a lot of work to get them to do engineering because it took a lot for them to even go to college. Most are back home now or going to OLC [Oglala Lakota College]. If there was some kind of support system that involved family, friends, and schools to make people do these things, I think it would make a big impact.

Where we’re from, the dropout rates are extremely high; so it doesn’t really cross minds to study engineering. The teachers know we drop out, so they aren’t as willing to teach us. If maybe we had better teachers who actually stayed longer than two years, they could make a difference in students’ lives.

Finally, AI students spoke of math as a barrier to engineering studies in comments such as these four:

In high school, they didn’t offer calculus or pre-calculus, so that hindered my experience here and discouraged me from majoring in a STEM field, because most STEM fields require something beyond Calculus II. I think that if high schools offered better math classes or prep classes for college that it would encourage more students to major in engineering.

Through high school, you got pushed through just to graduate. You didn’t really get the education you should have had or that you deserved from tribal schools. I feel like I didn’t get the education I needed to pursue the field that I am in now. I had to learn math and stuff like that on my own time during the summer in order to excel in college level academics.

I wanted to design things when I was younger, but when my math abilities hit a wall I had to pursue something that didn’t involve so much math. I was putting myself through college, and I couldn’t afford to retake a math class. Math books are expensive, and also it required a
lot of time, and I was working 40 hours a week. If I had more financial help as a student, then I probably would have gone in that direction.

Some students might not be attracted to it [engineering] because they don’t feel confident in math or science. From what I’m familiar with, math was a big obstacle for a lot of students, and science wasn’t a very well-studied subject in school either. Math and science were based off college readiness tests. I didn’t have that many problems with math and science in high school, but math was really heavily complained about, and there weren’t a lot of classes for science.

Non-AI Student Comparison: What Might Have Encouraged You or Your Friends to Study Engineering? (Question 13)

Non-AI students reported the following in response to Question 13:

- Need more family or friends in engineering, 37 percent
- More information, 37 percent
- Encouragement, 33 percent
- Need to like math, 30 percent
- Money reward or pay incentives, 23 percent
- Need to be smart/genius, 20 percent

Overall, non-AI students generally reported the following, all of which is consistent with AI students’ reporting:

- Engineering is not seen as a helping profession concerned about people and incorporating idealistic goals, attributes that students seek in careers.
- Engineering studies might be of more interest if students had more relatives and friends in that field.
- Students need more information about engineering in high school and more encouragement to study engineering.
- Inadequate preparation in math is a barrier.

Factors Influencing Selection of Major (Question 14)

Table 5 summarizes rankings of factors identified as influential in selecting post-secondary majors for AI students and non-AI students. Personal interest ranked highest, averaging between “substantial” and “very extensive” influence. Family, school activities, and outside school all scored with an average near “some” influence. Overall, when comparing the two groups, there were no statistically significant differences.

Table 5. Influence of factors in selecting post-secondary majors

| Study Population | Average Score |
|------------------|---------------|
|                  | Family | School Activities | Personal Interest | Outside School |
| AI Students      | 3.3    | 3.0               | 4.5               | 3.0            |
| Non-AI Students  | 3.0    | 3.8               | 4.7               | 3.1            |

*Note: Rankings of factors: 1=none; 2=little; 3=some; 4=substantial; 5=very extensive*

**CONCLUSION**

We analyzed interviews from 107 American Indian students (AI students) and a comparison group of 30 non-American Indian students (non-AI students) of prime college age, all currently non-engineering majors, all of whom consider South Dakota as their home state. Student interns
conducted standardized interviews to seek insight into the questions: “Why don't more American Indians study engineering and select engineering careers in South Dakota?” and “What would it take to attract more?” The main finding of this study is that the effects of poverty and the resulting survival mentality divert attention from what are perceived to be privileged pursuits such as engineering education.

In contrast to the non-AI students, AI students’ parents had a much lower achievement rate of bachelor’s and higher degrees, a standard requirement for entering the engineering profession. AI students were much more likely than non-AI students to report being underprepared for post-secondary educational pursuits, either academically or socially, and they were more likely to report financial concerns and to make negative statements about personal well-being and poverty, such as the many sub-themes under the heading of School Experience in response to Question 6. Twenty-three percent of AI students reported math as a barrier to engineering, compared to 30 percent of non-AI students.

Generally speaking, the study indicated the importance of consistent attention to the following needs: 1) amelioration of poverty; 2) understanding of what engineering is and its tribal relevancy; 3) exposure to engineering with American Indian cultural emphasis in K-12 schools; 4) presence of role-model engineers in their daily lives; 5) encouragement and support from their peers, families, teachers, Elders, and tribal governments to value STEM education, particularly engineering fields; and (6) the embedded perceptions of math as a barrier to engineering studies.

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ARTICLE

Out of the Depths: Engineering, Submersibles and Assemblages

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Environmental concerns about the state of the world’s oceans have been growing over recent years, particularly as acidification, overfishing and the limited capacity of the oceans to absorb CO\textsuperscript{2} from climate change have come to the fore. Engineering practices and innovations in a number of forms are of direct relevance to this, notably through a concern to develop engineering in such a way as to be for the benefit of all, including the non-human world. This article argues that assemblage theory offers an alternative way of understanding how culture is always already a part of nature, and that human autonomy has to be seen as constrained and limited if the worst effects of pollution and climate change are to be addressed.

KEYWORDS: assemblage theory, carbon capture and storage (CCS), marine biology, New Materialism

This article will examine current developments from within marine biology, assemblage theory and engineering, not necessarily an obvious combination of disciplines, but one that will aim to illuminate how collectively they can address some of the more serious environmental challenges that are now to be faced. It will be established that this forms a legitimate concern for engineering; that what happens in the oceans is of considerable importance for the future of the planet, and then that the new approach represented by this particular philosophical concept provides exactly the linking between the disciplines that is required. Once this territory has been laid out, the aim is to examine some specific areas in greater detail in order to consolidate the argument.

* * *

In a recent book on engineering as a means to working towards greater social justice, the authors suggested that the critical reflection required of engineers in this process involves asking three sets of related questions: who are we working for and whose needs are we serving?; how is the product or service created and is this being done in an equitable way?; and, who benefits socially and economically from the work being done? (Baillie, Kabo, & Reader, 2013). What is being encouraged is the creation of time and space for reflection and the willingness to enter into the liminal space or heterotopia that will enable appropriate courses of action to emerge (Baillie et al., 2013, pp. 90–91). There is no doubt that attempting to ensure that engineering innovations and practices are for the benefit of the whole of society must include concerns for environmental issues and ways in which both are developed either to improve the current state of the planet or to damage prospects for the future. Referring also to the work of Bruno Latour, one of the originators of assemblage theory, the authors emphasize that all decisions must be judged in the light of the specific context, with the understanding that none are neutral or value free, but that all contain values from the beginning, however implicit those might be. Thus one of the tasks for engineers is to identify the particular values that are always already embedded in the process, and to be prepared both to challenge those
and to propose alternatives (Baillie et al., 2013, p. 72). It will be argued that this entails a mapping that must go beyond the purely technological or scientific and that takes the discussions into the realms of philosophy, politics and ethics.

**MARINE BIOLOGY**

So why are the oceans so important for the flourishing of life, both human and non-human? As one of the accessible introductions to the subject of marine biology argues, we are beginning to appreciate that the marine environment and the organisms that live within it are critical to our wellbeing and survival (Mladenov, 2013). Thus, amongst other things, it provides us and our livestock with rich sources of food; it helps to stabilize the climate, which is critical as the impacts of human-induced climate change become ever more evident; it absorbs many of our waste products; it provides us with a wide range of biomolecules which are important in medicine and engineering; coral reefs and mangrove systems protect coastlines from erosion, and marine ecosystems support recreation and tourism throughout the world. Each of these is now under threat as human activities such as overfishing, coastal development, sewage disposal, plastic pollution, oil spills and the increased emissions of greenhouse gases cause significant damage to the marine environment and the life forms living in it. The pressures coming from the projected increase of the human population from seven to nine billion over the next forty years will intensify the dangers to this crucial source of life on the planet.

To add a little more detail to this: there is a growing scientific consensus that increasing global average air temperatures brought about by climate change are resulting in increasing global ocean temperatures. The average temperature of the world’s oceans is one degree centigrade higher than 140 years ago and is predicted to continue to rise during this century. This warming is causing a rapid decrease in the thickness and coverage of sea ice in the Arctic Ocean bringing its own dangers as sea levels rise and areas of human habitation come under threat. What is often less recognized is that the oceans are a vast reservoir of planetary carbon and that the world’s oceans are an enormous natural sink for atmospheric carbon dioxide. Currently they absorb about 25% of the roughly 35 billion tons of carbon dioxide emitted into the atmosphere each year by humans burning fossil fuels and deforesting the planet’s surface. Combined, the oceans and the forests account for about 50% of CO₂ being absorbed but this means that even now there is a 2 parts per million annual rise in the levels in the atmosphere and the pre-industrial level of 278 ppm is now greater than 380ppm and rising. Although there is much debate and controversy about what might be “safe” levels of this concentration, it could be that these have already been exceeded. One of the concerning impacts of this is ever greater acidification of the oceans themselves, with estimates that they are now 30% more acidic than in the pre-industrial era. Not only does this have a profound effect upon marine organisms and the overall functioning of the marine ecosystem, but it means that the capacity of the oceans to absorb increasing levels of CO₂ is becoming more limited, thus threatening unpredictable feedback systems in the overall climate. One possible impact is upon what is known as the Great Ocean Conveyor which currently moderates the global climate by distributing oxygen, nutrients and heat around the globe, but which may be adversely impacted by the ice melt and result in a drastic cooling of the European climate (Mladenov, 2013, p. 18). It does not take a great deal of imagination to work out that what happens to the world’s oceans is of great importance for the wellbeing of the planet and human society as a whole.

It will be shown in due course how engineering has a direct relevance to and impact upon these environmental concerns, but it now needs to be established how and why the philosophical ideas referred to earlier play a crucial role in this process. One of the major debates that has arisen as a result of the environmental crisis is that of how humans understand themselves in relation to what
might be called "the Natural World". It has been suggested that the problems humans have created are the result of seeing ourselves as lone autonomous individuals relating to the rest of nature only as if it is a resource to be used and exploited for our own instrumental purposes. This leads to the misguided view that such resources are either without limit, or can be replaced by substitutes created by human technology and ingenuity. Thus if one source of energy is about to run out or to become increasingly difficult or expensive to access—hence for instance the discussions about Peak Oil—we simply develop the alternative technologies to replace it with renewable sources of energy such as wind power or wave power. Whilst this is not to deny the importance of responding in this way, it begs the underlying question of whether, as humans, we have failed to acknowledge the ways in which we are not simply external manipulators of an inanimate resource, but are in fact always already part of the ecosystems which both shape us and are shaped by our technological culture. Thus we are challenged to develop new understandings of what it is to be human, but now in relation to all those non-humans, both other living creatures, but also the machines and technological devices which we like to think are our creations and which we imagine we control. The philosophical sources to be drawn on in this article pursue a critique of this limiting and damaging concept of human autonomy and suggest that what is required is an alternative discourse and conceptual framework which uses the notion of assemblages—an assemblage being a particular combination of the human and non-human functioning in a specific context, and within which the role of the human is more constrained and far less of a controlling factor.

ASSEMBLAGES

Up to this point in the argument the focus has been upon practical examples from marine biology and the environmental issues which are at stake. One has used the terminology of assemblages within this context in order to provide a general view of what is actually a quite technical and specialized development within philosophy, arguing that there are important ethical consequences of employing the term in this way. At one level this is a device for mapping the complex interconnections that exist between the human and the non-human and between different disciplines as they inform and shape what has been described as culture in its full diversity, but which I suggest is better seen as another aspect of the nature of which we are a part. It also proposes an alternative understanding of what it is to be human which challenges the established interpretation of individual autonomy and control, and which acknowledges that the human itself is always in the process of change and development and not to be reduced to some essentialist understanding. Each of these aspects of the theory is capable of much greater exposition than is possible in a short article, but it is necessary to offer some pointers to the thinkers involved, their basic ideas, and how this enables the sort of ethical judgements it is necessary to make. It needs to be recognized that not all of the theorists involved use the term in the same way, but that is less important than how it can be of value for the particular concerns articulated here.

A major interpretation of assemblages is that they provide a way of describing the entangled and complex nature of the relationships and connections which go to make up very specific contexts or situations that humans encounter, and of which we are always already a part. Thus one of the deep-seated problems that humans have created, is that we have differentiated our views of the world into a series of specialized disciplines and discourses, which serve now to produce division, misunderstanding and general lack of communication. One way of describing this is that we operate in silos, unable to cross apparent boundaries into other modes of thought or existence. This is a massively disabling factor as we struggle to address the very problems that have been created by the independent development of each of these areas, but without reference to each other, let alone to the insights and theories available from each discipline. To assume that this is simply an academic problem would be a mistake. In politics, for instance, one encounters a high degree of
disconnection, and the disillusion of many voters from the views and ways of operating of professional politicians. “They” exist in a small bubble surrounded by press officers and the media with whom they mix on a daily basis, apparently representing the vested interests of the elite groups from which they come, and making decisions about “our” lives without any direct experience of or reference to the realities which “we” face. How often does one hear this view expressed in our heavily compartmentalized culture? Yet political and commercial factors are often a crucial part of the mix—or assemblage—which constitute those matters of concern of which we should all be aware. In this way, the discourse of assemblages is a means of putting back together, orreassembling, the actual relationships and connections that determine or shape the lives we are leading.

This is not simply a matter, however, of reconnecting human relationships across various boundaries, although some of the theorists would not go further than this, but also of acknowledging the material world, the elements which we define as inanimate, but also recognizing that the human itself is fully material. So when we talk about the human and the non-human, the latter does not just mean other animate life forms such as those we encounter in the oceans, but also the basic building blocks or materials which form the rocks and undersea mountains, as well as the physical structures humans have created in order to explore them. Thus, for instance, the assemblage which is a new submersible, as will be seen later in the article, is itself determined by the materials out of which it is constructed—it is what makes certain activities possible and others impossible or less likely, and which enables humans to relate to the deep oceans in a way previously not possible. Hence assemblage theory is connected to what is called “the New Materialism” within philosophy, acknowledging the ways in which material reality shapes human responses, is also subject to human manipulation, and even more profoundly argues that what we call “the human” is itself already fully part of that materiality and as much in process of change and becoming as the rest of the “material world.”

A definition provided by one of the originators of this approach which sounds very technical but is consistent with my own description is as follows:

What is an assemblage? It is a multiplicity which is made up of heterogeneous terms and which establishes liaisons, relations between them, across ages, sexes and reigns—different natures. Thus the assemblage’s only unity is that of a co-functioning; it is a symbiosis, a “sympathy.” It is never filiations which are important but alliances, alloys: these are not successions, lines of descent, but contagions, epidemics, the wind. (Deleuze & Parnet, 2002, p. 69)

What this also makes clear is that the traditional way of thinking which places “things,” both humans and non-humans, into some sort of hierarchy, is now no longer adequate. So it is not about “lines of descent” but rather an acknowledgement that, as another contributor to the theory suggests “all things equally exist, yet they do not exist equally” (Bogost, 2012, p. 11). Now this is to take engineers and marine biologists out into the finer detail of contemporary philosophy and a liminal space where they might feel “out of their depth.” It could however be argued that one of the insights of the environmental movement is that the damage that humans have wrought upon the planet stems directly from our view of ourselves as somehow superior to the rest of creation, and thus in a position to exploit and manipulate “others”—sometimes humans but often non-humans—for our own interests and benefit.
Another thinker from this philosophical approach talks about “vibrant matter” and offers the example of the North American blackout in August 2003 to describe the interconnections which often remain hidden. She gives a similar definition of assemblages:

Assemblages are ad hoc groupings of diverse elements, of vibrant materials of all sorts. Assemblages are living, throbbing confederations that are able to function despite the persistent presence of energies that confound them from within. . . . Assemblages are not governed by any central head; no one materiality or type of material has sufficient competence to determine consistently the trajectory or impact of the group. The effects generated by an assemblage are, rather, emergent properties, emergent in that their ability to make something happen is distinct from the sum of the vital force of each materiality considered alone. (Bennett, 2010, p. 24)

This approach is characteristic of the New Materialism and has links to specifically ethical and faith-based understandings (Crockett & Reader, in press).

To set this out I refer to another of the major texts from this new source:

Thinking climate change requires thinking ecologically and thinking ecologically requires us to think how we are both embedded in a broader natural world and how non-human things have power and efficacy of their own. However, because we had either implicitly or explicitly chosen to reduce things to vehicles for human discursivity, it became impossible to theorize something like climate change because we only had culture as a category to work with. Having brought about the dissipation of the material in the fog of binary oppositions introduced by signs, there was no longer a place for thinking the real physical efficacy of fossil fuels, pollutants, automobiles, sunlight interacting with the albedo of the earth and so on. (Bryant, 2014, p. 4)

In response therefore, the task is to rethink the concept of society and indeed of humans themselves, and to propose that there is only nature, and that culture itself is a formation of nature. Within this there is a multiplicity of assemblages containing humans and non-humans, the latter also including the machines and technological devices that are the means of engineering contributing both positively and negatively to the environmental challenges collectively to be faced. The ethical task ahead is to identify which are the positive and constructive assemblages and which the damaging and sometimes deadly ones. We need to question in each specific instance what it is that a particular assemblage can do and to evaluate its contribution to the wellbeing of the whole.

ENGINEERING

Moving now to consider some engineering projects that attempt to address the issues above from the sphere of marine biology, and also climate change more generally, we remind ourselves of the questions to be asked. Who benefits from these—and this must include reference to both human and non-human—and what values are at work, either implicit or explicit? This will enable the critical mapping of the projects as specific assemblages and assist in determining the extent to which they are constructive or destructive.

A report in the journal *Process Engineering* on October 2nd 2014 recorded that the first commercial scale Carbon Capture and Storage (CCS) plant was to begin operating on that day in Canada (McKenna, 2014). The 110MW coal-fired power unit with amine capture technology is claimed to be able to capture around 1 million tons of CO2 each year, thus cutting the unit’s emissions by 90%. The facility has cost around £751 million to build. At the moment Europe lacks a pipeline of CCS projects and lags behind in terms of technological development, although there are two
commercial-scale CCS projects being developed in the UK, at Drax and at Peterhead, under a government programme. Both would transport CO$_2$ to the North Sea. This first project to come into full operation is being claimed as a major breakthrough in showing that brown coal can be used to generate electricity with only one quarter of the carbon emissions of natural gas and one tenth of the emissions caused by burning coal historically. So who benefits? What values are involved? What assemblages are to be identified? It is not easy to evaluate, but such technology and advanced engineering is not universally accepted as either being without faults, or necessarily a good way of tackling the challenges of climate change. The obvious immediate beneficiary will be the energy industry itself as it allows sections of it to continue operating when many would argue that coal-fired power stations and their proliferation in places such as China, are the very units that should no longer be built and their expansion limited if not prevented altogether. It is not known as yet whether the impacts being claimed for this process can be delivered, therefore their benefit for the non-human in terms of taking pressure off the oceans and their capacity to absorb CO$_2$ is a matter of conjecture. Clearly those directly involved in developing this technology will benefit financially. The other obvious aspect of this is the political one, and the extent to which governments supporting these developments as part of their overall energy policy, can claim to be mitigating the worst impacts of CO$_2$ and climate change, when in fact their actions are already a matter of “too little too late.” So is this an example of the use of engineering to provide window dressing for the politicians and their allies in the energy industry rather than a genuine attempt to address the wider problems? This particular assemblage of engineers, the physical products and components required for the plants themselves, the external funding sometimes government-based and, if not, privately resourced, the coal and its methods of extraction and burning, and then the CO$_2$ in whatever form it is then processed and dealt with, cannot yet be said to be unambiguously of benefit for the human or the non-human. The values would appear to be those of the established capitalist structures which still see the non-human as resources to be manipulated and exploited for the benefit of the few and to the detriment of the many, if indeed it is the case that this fails to stem the rising emissions of CO$_2$ globally.

Another less than obviously benign engineering innovation currently under development is to be found in the oil industry. In the light of the massive BP oil spill in the Gulf of Mexico a few years ago, the impact of this arm of the energy industry is also under scrutiny. The state funded and controlled company Statoil in Norway, is developing a series of underwater plants connected by pipelines that can operate effectively at a deeper level than previously possible. This again, it is argued, will enable normal extraction processes to continue whilst limiting environmental impacts and damage. Without state funding no company could afford to take the risks of developing this form of technology and the engineering expertise required. So very much as with the CCS plant, this is a project which makes claims that are yet to be substantiated in practice; which enables the energy industry to continue some form of business as usual; which encourages rather than challenges dependence upon non-renewable sources of energy, and which appears to support the assemblages of corporate interests, government policies and the financial concerns of those developing the technology and implementing it. Whether this particular development within the field of Sub Sea Oil and Gas is really of benefit to the wider planet then is a matter of debate to say the least, but it will no doubt be presented to the public as another means by which human ingenuity and investment is being employed to counter the effects of environmental damage, whilst allowing corporate interests to continue unchallenged. Hence media and public relations coverage is another aspect of this type of assemblage and needs to be viewed carefully and critically.

Related to both of the above is of course the plastics industry, the materials being derived from oil and gas, and both a source taken for granted in our culture and also a major component of human waste. Huge amounts of plastic waste end up in the oceans, flowing down rivers, sewers and storm
drains. Boats are another source of plastic pollution with materials being dumped overboard and
fishing boats discarding large amounts of fishing gear. One of the problems with this is that plastics
take a long time to degrade, hence the oceans are subject to an ever increasing level of plastic debris
both floating on the surface and also sinking to the seabed. Similarly, plastic debris on shorelines is
also a problem. An example of the levels of ocean-going plastic was a study collecting plastic in the
North Pacific gyre which revealed an average of 334,271 pieces of the material per square
kilometer (Mladenov, 2013, p. 58). This is harmful to many species of marine life which either
become entangled in it or ingest it. Seabirds and sea turtles are particularly at risk. Although some
measures have been put in place to agree to limit the levels of disposal these are difficult to monitor
and enforce. The obvious response to this would be to develop and encourage more means of
recycling the waste on land before it ever reaches the oceans, and there are indeed resources for
this from within materials science engineering which need to be more widely disseminated and
implemented. However, this is yet another assemblage which involves politics, the media, the
lifestyle of ordinary households, as well as the engineers who develop the technology, and of course
the physical materials themselves and their potentials for change over time. At the moment this
particular assemblage is detrimental to the wider planet but it is one that could be turned around to
become of benefit.

A development that is perhaps more positive is that of submersibles mentioned earlier and which
are now able to take humans down to ocean depths previously not possible. Triton small
submarines or submersibles are now available as a result of engineering advances and are being
used for the purposes of deep sea exploration. The irony however, is that these were originally
developed as a purely commercial product, and the latest accessory for those millionaires who own
sea-going yachts and who wanted an “experience” that only the most wealthy could enjoy. As with
so many of the assemblages we have identified, there is an ambiguity about the process and the
impact of the engineering technology so that there are benefits for the few which can sometimes be
turned around to the benefit of the many, but only when sufficient funds or political will is available
to make this possible. Why are these submersibles of value for marine biology? The deep ocean has
been believed to be a dark and lifeless environment, although it is the largest ecosystem on the
planet, covering 80% of the entire global ocean and 79% of the planet’s habitable living space. Yet,
until recently, it has been largely inaccessible to humans. There is little light, extreme pressure and
low temperatures and yet there is a great diversity of marine life present. Up until now only about
5% of the deep ocean bottom has been explored using remotely operated robotic vehicles and less
than about 0.01% has been surveyed in any detail (Mladenov, 2013, p. 105). Now it has become
possible for humans to go down into the depths in safety through the development of submersibles,
a whole new world has opened up and we can begin to learn more about the life forms which are an
integral part of the lives we share on the planet. The questions this raise however are whether we
will see this as yet another “resource” to be exploited for human benefit, or whether instead this
ecosystem will be valued in its own right and its integrity and existence respected. Once again then,
it all depends on whether or not humans can change their understanding of the relationship
between nature and culture, and grasp that culture itself is simply another component in the
greater assemblage that is the world of which we are all a part, and over which we do not and
cannot exercise some sort of proprietorial control. Philosophy, politics, marine biology and
engineering form together the combination of disciplines which will shape the human response to
the non-human ecosystem of the deep ocean.

* * *

In summary then, it has been shown that assemblage theory provides a means of analyzing
engineering developments and innovations in a way that reveals the interconnected and complex
nature of the interactions between the human and the non-human, those including more than just other animate creatures, but also the material components which are both shaped by and shape those interactions. Rather than presupposing a hierarchy of beings with humans at the summit and everything else demoted to being a resource to be manipulated or exploited, this flat ontology assumes a much more level playing field within which humans are not lone autonomous individuals, an understanding of which is seen to have been so damaging to the planet, not least as perceived through marine biology. Thus it also suggests a means of making ethical evaluations of such engineering advances based on whose interests and needs are being served. Each assemblage must be examined in detail in order to assess whether it is damaging to the whole or of benefit to it, and only then can alternatives be proposed and developed.

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