MUSINGS ON RE-STORYING RELATIONSHIP WITH EDUCATION

The following chapter presents one potential approach to re-storying relationship with education. This approach is intended not only to support Indigenous students, but to benefit all learners. This commentary is grounded in lived experience and draws on personal conversations, observations, readings, and critical self-reflections.

Many editorial changes were made between submission of the final draft and publication. While most were not substantive enough to warrant individual mention, some of these changes merit further reflection. Where applicable, the [original text] is included and explanatory commentary has been provided in footnotes. Although a more comprehensive discussion was considered, it was decided that this process warrants a dedicated exploration beyond the scope of the present work.

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Learning Objectives

1. Understand the “Ethics of Reciprocity” and the responsibility of scientists to land stewardship, as well as to environmental and social justice, using chemists as an example
2. Recognize the importance of identifying and acknowledging personal biases, and of giving consideration to diverse worldviews.
3. Comprehend the importance of addressing justice and decolonization questions in science education and how both can influence the role of scientists and their contributions to society.

THE STUDY OF SOCIAL INNOVATION AND SOCIAL JUSTICE are typically associated with the social sciences. However, developments in the natural sciences and engineering substantially impact the fabric of our societies and their priorities for innovation. Moreover, many problems and opportunities created through natural science innovation can cause or address social and environmental justice questions. As such, an argument could be made that questions of social innovation and justice need to be part of natural research and learning. We use the example of chemistry to focus this argument and to provide

concrete examples of how questions of justice, decolonization and innovation need to be considered in natural sciences and engineering education.

Chemistry has traditionally been taught as a body of knowledge that builds on the historical discoveries of those deemed "important" chemists; *and a critique of the fixity and limitations of boundaried, disciplinary knowledges can be seen in Chapter 2.* In Chemistry, students are expected to transform into chemists by learning a particular body of knowledge and its respective, historical context. Students must learn outdated concepts simply because they are the historical foundation of current knowledge, only to later unlearn information that is neither effective nor pedagogically useful. Recent innovative initiatives in chemistry pedagogy have proposed that chemistry education be approached in a manner where students are taught to think like a chemist rather than focusing on chemistry as a body of knowledge (Talanquer & Pollard, 2010). This paradigm shift prioritizes cognitive skills, problem-solving, and a deeper understanding of scientific reasoning over rote memorization of facts and theories. While this shift addresses some of the pedagogical practices of traditional science education, it does not go far enough in addressing very real-world societal implications.

Science, and certainly the field of chemistry, is not isolated from the world it aims to understand and transform; it is a discipline deeply embedded in societal, economic, and ethical contexts. Scientists, despite their allegiance to the tenets of scientific objectivity, are not just brains in lab coats; they are individuals shaped by their own cultural, ethical, and societal worldviews. This inherently influences not only what questions they choose to investigate, but also how they interpret data, and most critically, how they apply their discoveries. For example, considering the impact that chemical innovation is having on our society–from increased life expectancy due to medical innovations to health crisis due to pollution–chemists like other scientists have a unique opportunity (and we would argue, responsibility) to help address a variety of environmental and social justice questions.

As we face numerous global challenges ranging from climate change and pollution to public health crises, there is a growing need to train scientists such as chemists to be not only skilled at making and manipulating molecules, but also to be capable of grappling with the ethical and justice-oriented questions that their work raises. This transformation necessitates a paradigmatic shift in the sciences, from asking the question of "Could we?" to the far more impactful question of "Should we"?

This chapter is a conversation between Brooke Filsinger, advisor for Indigenous education and decolonization for the Faculty of Science at Toronto Metropolitan University (TMU), and Roxana Sühring,

a faculty member in TMU's Department of Chemistry and Biology, whose research and teaching focuses on chemical contaminants and contamination as a justice issue.

INTRODUCTIONS

Roxana: My name is Roxana. I am a German female scientist who moved to Canada a few years ago. I grew up in a household of scientists and environmental activists. During my doctoral research on environmental contaminants, I learned about the outsized impacts of contaminants on Arctic communities – and this was the moment when I realized the interconnectedness of environmental contamination and justice. Since finishing my PhD, I have worked on questions around chemical transport into Arctic communities and other communities that have been impacted without having a say in, or benefit of, the industrial processes that caused contamination there. As a chemistry educator, I am hoping to make students aware of their power and responsibility towards **environmental stewardship** and its connection to environmental and social justice.

Brooke: Wa'tkonnonwerá:ton. Brooke niyónkyats. Kanyen'kehá:ka niwakonhwentsyò:ten. Ohsweken nitewaké:non nek tsi tkí:teron tsi tkarón:to. My name is Brooke. I am a mixed-raced female of Haudensaunee and settler ancestry. I was raised outside Community and have been working to find my way back. While conducting provincial health research for nearly two decades, I simultaneously danced and taught my way across **Turtle Island**, Europe, and Asia. My experiences within this dance community were instrumental in informing my strong beliefs around social justice education and community-building/caretaking. I returned to academia as a PhD student with a research focus on the inclusion of Indigenous pedagogies and research methodologies in Science, Technology, Engineering and Math (STEM), privileging the Indigenous student experience. While I bring my perspective to my research and the thoughts I share, I speak only for myself.

Given our respective academic positions – faculty member and student/advisor – it is important to acknowledge that our relationship is subject to the complexities of the power dynamics of the academy's hierarchy between students and professors. However, our relationship was built on friendship long before either of us arrived at the university. We have chosen the ethical stance to view each other reciprocally as both teacher and student. We draw from our respective expertise and acknowledge the areas where we still have much to learn. We approach this relationship from a place of honesty,

vulnerability, humility, and partnership. We further acknowledge that we have not come to the understandings and beliefs we discuss in isolation. Our learning journeys have been profoundly enriched by the immense generosity of many, with special acknowledgement to the invaluable contributions of Caleb Wesley, Amy Desjarlais, Alacea Yerxa, Sommerly Grimaldi-Ertl and numerous others among the Indigenous Community at TMU and beyond. We have intentionally included specific individuals in the introduction here, as opposed to in an acknowledgement section at the end, because the learnings in this chapter were heavily influenced by their knowledge-sharing. We do so in an effort to bring Indigenous Knowledges and Oral Tradition practices into academic spaces, even when there is no paper to cite! We are grateful for their support and the wisdom they have generously provided in the past and continue to share with us.

Although presented as a conversation, the following dialogue should not be interpreted merely as a transcription, but rather as a co-constructed reflection based on numerous conversations, interrogations of colonial academic practices, lived observations, shared reflections and collaborative learning over the past two years.

WHY WE NEED TO CONSIDER ETHICS AND SOCIAL JUSTICE IN CHEMISTRY EDUCATION

Roxana: This chapter talks about why it is necessary to teach considerations around ethics and social justice in the sciences, and specifically, in chemistry education. I will start with my perspective as someone who is a chemistry educator, as well as a researcher who works at the interface of chemistry and justice questions.

I would say that chemistry and social justice interface most around contamination in the environment. In fact, I would argue that a significant portion of our current pollution problems might originate from the absence of justice-centric chemistry education. We have graduates who have spent years in chemistry programs and have, at best, taken one course on the ecological consequences of chemical processes. The conversation on potential, unintended consequences of chemical production and use is practically non-existent. So, it is not surprising that questions like potential environmental harm and environmental injustice are not sufficiently considered in most chemical designs.

This lack then leads to a disconnect between the push for more sustainability and the chemical synthesis practices, not just in education but within the discipline of chemistry, in general. For

example, perfluorocubane — a per- and polyfluorinated substance (PFAS) — was chosen as "Chemical of the Year 2022" by the American Chemical Society's Journal *C&EN* (Krietsch Boerner, 2022), and it *is* a fascinating molecule. I am sure it is really interesting to think about the synthesis, properties and potential applications. But it belongs to a category of chemicals that environmental chemists and regulators are flagging for their environmental and human health impacts (Cousins et al., 2022). PFAS are of concern because they are highly stable in the environment — sometimes called **forever chemicals**; they are associated with numerous health impacts, like endocrine disruption and cancers; and they are often not effectively removed in water treatment (Cousins et al., 2022). They have fascinating properties though, and are incredibly versatile, which means that, from a synthesis and industry perspective, they are great molecules.

The problem is that the prevailing philosophy in our field is still mostly centered around discovery as the ultimate goal of research. It operates on a principle of "if it is possible, it is worth pursuing," which means that what fascinates us academically ends up overshadowing the urgent issues, like the chemical pollution that we now confront. What we need is a reorientation where we think about potential consequences before making chemicals, and we need to make sure that this change of thinking happens early on in chemistry education. This is why I think it is important to have questions of ethics, impact and justice in a chemistry curriculum and in literature about chemistry education.

Brooke: I am coming at this question from an entirely different perspective in that I haven't been involved specifically with chemistry education in any capacity for many, many years. But I do focus a lot of my time and energy reflecting on creating space for Indigenous Knowledges within STEM education and research, in particular, as well as on approaching education and research from a more [w]holistic[1] perspective, in general. With that noted, I am typically not only considering the physical and mental areas where we tend to focus our energies in academia, I am also concerned about heart and spirit. How do these concerns relate to a scientific field, like chemistry, where traditionally heart and spirit would intentionally not be given any consideration? Are we able to find a more [w]holistic balance?

[1] The distinction between *holistic* and *wholistic* carries particular significance within Indigenous contexts (Miles et al., 2023). The use of *wholistic* in the original work was a deliberate and intentional choice, reflecting an emphasis on the inseparability of the physical, mental, emotional, and spiritual.

When I think about social justice in chemistry or chemistry education, I recognize there is an extensive body of knowledge that students are expected to learn. It is not until students are quite advanced in their education that they begin to question or challenge where these knowledges come from? Are these knowledges correct? How have they changed over time? These are questions that students are not allowed to ask until they have already accepted these knowledges and the foundation on which all their understanding has been constructed. Maybe I am a contrarian, but I believe there should be opportunity to start questioning from the very first day, inquiring:

- Who is asking the questions?
- How has this knowledge developed?
- Who has formalized what is “accepted”?
- What knowledge and viewpoints may be missing?
- Have our personal biases given rise to gaps in thinking that need to be addressed and mitigated?

For me, these are the crucial questions in finding out who decides our accepted bodies of knowledge, what is genealogy, and who are the knowledge generators? With that said, other important steps, at least in my mind, is to identify our conscious or unconscious biases; position ourselves in our worldview; and understand our personal worldview in relation to others.

EDUCATION, WORLDVIEWS AND THE RESPONSIBILITY OF SCIENCE

Roxana: You've touched upon something incredibly important — the matter of perspectives, and by extension, worldviews. Our current chemistry pedagogy is almost exclusively taught from a **eurocentric** point of view. (Please note that we have intentionally chosen to use lowercase for “eurocentric” in an effort towards rebalancing the authority of Indigenous [and other] Knowledges.) It is as though the foundational texts and principles we teach are filtered through one specific, cultural lens and conveyed as absolute truths. It is a paradox, really, considering that later in their education, students are introduced to the idea that there is no such thing as an absolute truth. But what happens is that the eurocentric perspective is implicitly enforced as the canonical truth, and, in doing so, alternative ways of knowing – be

they biocentric, [w]holistic, or ecocentric – are marginalized. Imagine what would happen if students were exposed to these diverse perspectives from the onset? Wouldn't that invariably shape how they approach chemical research and development?

Brooke: I think that's a really important consideration! It is not necessarily detrimental to have personal biases or individualized worldviews, so long as we can identify what they are and appropriately address the potential gaps in our thinking. Understanding our worldview helps us to frame how we approach and understand research – our conclusions and interpretations – and what we do with these findings. All of which leads us to the conversation around the idea of objectivity or pseudo-objectivity. As scientists, we're trained to be so-called objective observers. Neutral. Impartial. Uninfluenced by our personal biases, emotions and preconceived notions. In practice, we each bring different knowledges, experiences and beliefs to our work. Even though students and scientists are taught to be objective in methodologies, analyses and conclusions, none of us can truly be objective. At best, we employ pseudo-objectivity. This understanding should always inform our work and interpretations, but it is rarely acknowledged.

Roxana: We have talked about this previously and again I think this is such an important point – objectivity and the lack of objectivity. The questions we pose and the intellectual lenses through which we view the world shape the conclusions at which we arrive.

As a student, I had a great exercise in my second year, which highlighted this point. We were given two papers on the exact same topic – one written by environmental advocates and the other, by industry. Despite using virtually identical data sets, the conclusions the authors arrived at were completely different. That experience really exposed the inherent subjectivity in data interpretation and shaped my way of reading scientific literature.

This discussion ties back into our point about worldviews, but also to another important point that I have been reflecting on a lot: the responsibilities we have as scientists. I would argue that there's the universal human responsibility to be stewards of the Earth. But there is an added layer of obligation for us as scientists living within treaty territories. The treaties obligate us to share the land, to leave something behind, to keep it clean, and to only take

what we need (Loft, 2021). When we understand ourselves as part of, or guests [within]upon[2], these treaty lands, we should ask ourselves what these treaty obligations mean if we are, for example, making, researching or using chemicals. The exploration and understanding of diverse, and particularly Indigenous, worldviews are not just something that is "nice to have". It is not something to simply make us a more critical thinker. It is how we honour and abide by our treaty obligations.

CRITICAL THINKING

Brooke: This point around treaty obligations is so important. And I am glad you also raised the idea of critical thinking. Often critical thinking, a crucial cognitive skill that must be developed and requires practice, is overlooked or is one of the last things taught in science education. I had a recent conversation with one of our Indigenous students who was questioning why critical thinking is only taught in undergraduate fourth year and only in particular programs within our faculty? They believed, as do I, that these concepts should be presented much, much earlier in their education.

By the time students get to fourth year, a lot of their ideas are fully formed, and they've already accepted one particular way of verifying "truth". But there are students, Indigenous and others, who are potentially starting a post-secondary education with a completely different worldview and understanding of science – what science is, and ways of generating knowledge, understanding and relationships to the world. In the case of Indigenous students specifically, they often are already understanding and upholding treaties that are not being upheld on the other side. So, when these students, with different worldviews, enter a post-secondary institution, they're being asked to learn and to accept knowledges that they potentially have been questioning from day one. The other students, on the other hand, may not even realize that they can question this knowledge and that they can ask where the knowledge is coming from. And perhaps even more importantly, that they can look at the knowledge generators and can [consider]question[3] their **positionality**.

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[2] "Within", reflects an understanding that we are to be in reciprocal relationship with, and hold responsibilities to, the Land. Replacing this with "upon" introduces a sense of separation or dominance that conflicts with this worldview and risks unintentionally reinforcing colonial ways of thinking.

[3] To "consider" one's positionality is to reflect on their self-location (i.e. how they have situated themselves within their work and in relation to Knowledge). Reframing this as "questioning" risks implying doubt or invalidating those

I recently taught a graduate course where we discussed the idea of positionality – stating who you are and what you are about. What do you bring to the science? How do you understand your role and your position? What do you want me to know about you? This was a really radical concept for a lot of graduate students – science students – to have to state their position in relation to their work, whereas I would argue that it is fundamental to understanding how you got to the place that you got: your research methods, your research question, your analysis interpretation, how you're choosing to approach future work, all of these matters link integrally back to your positionality as a person. And so, in understanding your positionality, I can understand your work. But in removing that positionality, you remove such an important piece of my ability to understand and relate to this body of research that you're producing and disseminating.

Roxana: Absolutely. Your point on critical thinking and our place in science education is so important. It is fascinating, is it not, how critical thinking as a skill — crucial for any scientist — is often treated as almost an afterthought or something that you will "pick up" during your studies? While undergraduates are, in an ideal world, trained to find and interpret scientific literature, they are not taught to identify biases. It is somewhat paradoxical, considering that any scientist does precisely that: gauges the reliability of a study by assessing affiliations, previous research and other such factors that could potentially introduce bias. That ties into your point on positionality. The supposed objectivity in science demands a researcher to separate themselves from their work as though their personal, social, and ethical perspectives were contaminants rather than assets. This is ridiculous. After all, we are inseparable from our thoughts, lived experiences, cognitive frameworks and ethical compasses. So how can we identify biases if we ignore ourselves and others as parts of the interpretation of [their]our[4] research? This also circles back to our earlier conversation on social justice. If scientists were encouraged and trained to bring their full selves into their research, their work would probably be more ethical and socially aware. I believe that it would naturally prompt us to consider the broader implications and consequences of our work.

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reflections, undermining the integrity of self-determined identity rather than recognizing their positionality as an intentional and meaningful act of relational accountability.

[4] "Their" research highlights the importance of recognizing potential sources of bias in the work of others, while "our" research shifts the focus to self-reflection. While both are essential research practices, the initial wording emphasized critical engagement with external sources, with the understanding that introspection should already be a foundational expectation of ethical research.

The other point you touched on that I believe is critical is the disempowerment of students in an academic setting that only presents one way of seeing the world and generating knowledge. This power dynamic, through how the material is presented but also through grading, for example, effectively quashes any critical thinking. It is a problem that we, as educators and researchers, must address if we want to educate more reflective, critical and just scientists. *In this collection, Chapter 6 offers examples of innovative pedagogical practices that could enrich critical thinking towards social transformation.*

RELATIONSHIP IN SCIENCE AND THE NEED FOR LESS OBJECTIVITY

Brooke: I agree; and I would argue that even though some would give lip service to the idea that you can challenge professors, in reality, it is generally not encouraged or practised. There is still very much that dynamic of "I convey the information and you accept the information". This is perpetuated by the way science education is practiced. Much of the time, at least when I was a student, it was one-way learning – basically, an information dump. And if you do take it away and question it or sit with it or find limitations in its thinking, there's rarely, if ever, that opportunity to have a more fulsome discussion because it is always on to the next concept. So even if, from a professor's perspective, they are open to that opportunity for students to dialogue, challenge or question, this dialogue, in practice, is not really given the time or space that would be needed to develop this skill. Because it really is a skill that needs to be developed and practised by students. And again, I think a lot of the onus is put on students to understand that they can do this type of questioning work and to do it themselves – to create the time and space themselves to develop these critical skills they probably do not even recognize as being important; and really a lot of students just do not have the time nor the energy to do it, especially when it is not given priority.

One of the other things you were talking about, to which I want to return, is our relationship to our research. I am always thinking about relationship. From my particular worldview, when I am thinking about research, I am really thinking about trying to understand whatever it is I am researching by being in relation with it. So, the more relationship I have or the closer I can get to whatever I am trying to understand, the better my understanding will be. I think that's a piece that's also missing from a lot of education: that relationship with each other, with our professors, with the academy, with the land. We try to remove that idea even though we

inherently are in some sort of relationship. If we're not caretaking that relationship and understanding that it *is* a relationship, then things have potential to go downhill really quickly. There's the possibility for imbalance, misunderstanding, and the potential to develop these skewed views about power and power dynamics. You *can* ask questions, for instance, but what questions *should* you ask?

Roxana: Exactly. I love your point on relationships not only with each other, but with the things we research, our institutions, the land and the community that this research will impact. But that is in such a stark contrast to the idea that "good scientists" should take themselves out of their research. This idea of pseudo-objectivity, where we are led to believe that the mind can function in isolation, it is incredible how pervasive this idea is. I mean, neuroscience itself would counter such a reductionist view. Our frontal cortex is not operating in a vacuum, separate from our emotions or social context. Max Weber argued as early as 1904 that there is no science free of value, judgment and personal perspective by the researcher (Goddard, 1973), but the contrary argument is still stubbornly made.

Speaking of context, let's talk about the elephant in the room: academic evaluation. Our current grading system sets up the professor as a sort of gatekeeper, doesn't it? Students are not just navigating the material; they are also navigating the power dynamics in academia. If the endgame becomes about securing that "A", what room is left for meaningful critical thought and learning? It really worries me. We're in institutions that are supposed to foster intellectual curiosity and critical thinking, but grading metrics and other academic hierarchical structures, including "hidden curricula," end up stifling those very attributes. Students become risk-averse, not because they don't want to put the effort in, but because the system incentivizes a certain form of academic conformity. It is as if we are teaching them that the ultimate prize is not understanding but rather a certificate that symbolizes it. So, in essence, the academy runs the risk of becoming transactional, when what we need is a more relational, even transformational, educational model.

MOVING FROM "CAN WE" TO "SHOULD WE"

Brooke: Just as you were talking, I was also recognizing that long-time tenured professors, and those who have been in their respective fields for quite some time, are potentially disadvantaged in that they have built this whole body of knowledge and understanding without ever having to

consider other viewpoints, without ever having to reconcile the idea of pseudo-objectivity, biases and bringing their worldview to their work. They are not necessarily equipped with these skills either; and it could potentially be quite daunting to be challenged, which I think disincentivizes professors to shift their work and thinking. Working in this way does require more thought, more thinking, more reflection, and more self-evaluation; and again, there's not necessarily always the time, the space and the willingness to do that, particularly within the constraints of a post-secondary education or institution.

Roxana: Yes! And that brings us back to how the way we see chemical research is tied to what society thinks is important. The problem is that the focus is on "What can be done?" rather than the crucial question of "What should be done?" So, then the question is "How can we shift chemistry education to [also][5] instill a strong sense of social responsibility?" We owe it to our students, and the communities they'll eventually impact, to equip them with the tools they'll need to question, challenge and ultimately change the way things are. So how do we create a curriculum that goes beyond mere mentions of ethics and social concerns and embeds these issues into the core of how we teach and understand chemistry? This would mean teaching them that, as chemists, our job is not "just" to just ask whether a new molecule can be made, but also what the broader impact of that molecule would be on public health, social equity, environmental sustainability and even global politics. That would mean a change not just in the curriculum but in the entire academic culture, which would make a lot of people very uncomfortable, as you said. It would basically challenge what it commonly means to be "a chemist" or "a scientist".

Brooke: And from my perspective, coming from both my worldview but also my background and work in public health research, it absolutely blows my mind that these questions are not being asked! And that there is no consideration around the situation of "I *can* make this molecule but *should* I?" How is it not front of mind to consider the impacts of making these molecules? What are the long-term impacts, not only on me and my environment, but the environment of my children and my children's children? Will these molecules still be impacting things down the road? Particularly when we have examples of exactly this happening. Things we created thirty, forty, fifty, eighty years ago are still impacting our health and our environment today,

[5] "Also" emphasizes the expansion of current educational practices to instill principles of social responsibility alongside technical training, advocating for a more wholistic approach rather than a replacement of existing pedagogical foundations.

and our capacity to create has since exponentially increased. And with that, so has our capacity to choose to do harm or choose to do good. It really does blow my mind that these questions are not the first questions that are being asked. That is not to say that we cannot be curious, that we cannot be curiosity-driven, but I think that there is a responsibility to have these considerations along with that curiosity.

Roxana: Yeah, I absolutely agree, and I think that is such a fundamental point of why we need to talk about this matter, and why it is so important to re-evaluate how we teach chemistry, in general. It is so strange that the ethical dimensions of chemistry are only talked about in graduate studies or toward the very end of undergraduate education – if it gets talked about at all. We should teach a sense of social and environmental stewardship from the moment we start introducing students to chemistry in high school. It would be so impactful if we educated young students on the benefits, as well as the risks, of chemical innovation. That would mean that we are educating critical thinkers who know how important it is to ask not just how, but why, and at what cost. There have been some recent publications where this is being discussed: for example, conversations around the need to raise "essential use" as a concept when thinking about chemical registration and regulation (Figuière et al., 2023). This means that the question of "Do we need it?" is finally being considered rather than just the question of possibility, or even, profitability. Another recent paper argued that the chemical industry and chemical research has to change to make sure that modern chemistry is not "rubbish" (Flerlage & Slootweg, 2023).

Brooke: Oh, amazing!

Roxana: Yeah. "Modern Chemistry is Rubbish" was literally the title of the publication. Unfortunately, these issues are discussed by a narrow group of environmental chemists and environmental scientists who work on pollution issues. The "Molecule of the Year" that we talked about earlier exemplifies this paradox. How can we laud a PFAS compound when its potential ecological impacts are so horrendous (Cousins et al., 2022)? We have been advocating for PFAS restrictions; and PFAS have been the subject of intense scrutiny and regulatory debate (US EPA, 2018). To celebrate it is like patting ourselves on the back for causing maximum ecological harm.

But again, the questions are “What can we do about this?” and “How do we reconcile sustainability, curiosity-driven chemistry research and a profit-driven chemical industry?” From the days of the alchemists, chemistry has been trying to understand natural phenomena and advancing materials, human well-being and our knowledge. Questions of “What can be made?” and “How can it be improved?” have driven the field. But the question has rarely been: “Just because I can, should I?"

MOVING SCIENCE OUT OF THE VACUUM

Brooke: I think for me it all goes back to this question: “Are we doing science in a vacuum?” Also, “Are we teaching science only in the lab? Or, are we throwing out that idea of objectivity and moving toward an understanding of our place in relation to the world in which we live?” If we understand that everything we do has an impact on our environment and our relationships, then I think we understand that it is not just a molecule that I’ve created in a vacuum and it is really incredible. It is that this molecule has real impact, or at least has the potential to have real impacts, and with that I have a responsibility, to the best of my ability, to ensure that those are not harmful impacts. I have a responsibility to myself and to my relations, be those my human relations or the non-human beings inhabiting this planet, to consider the potential impacts of this molecule I’ve created, and to ask whether they are greater than any potential benefits? Are there long-term impacts? That is, is this molecule going to create problems?

With the way that science is currently taught, for the most part, it is very easy to separate ourselves from these incredibly important considerations. We recognize all the previous, amazing discoveries and the dreams of discoveries still to come, and we build on the foundation [of that knowledge][6]. And we only briefly educate without full understanding (or commonly, not even acknowledging), the negative impacts of these scientific discoveries. But when we understand that we don't operate in a vacuum and that everything we do has an impact, I think it is a lot harder to [just][7] flippantly create molecules or create chemicals or have a PFAS be the molecule of the year. Because we understand that there are real-world,

[6] Within an Indigenous paradigm, Knowledge is understood to be relational, tied to time and place, and often carrying responsibilities to the People and Lands from which it emerges. Indigenous epistemology acknowledges the genealogy of Knowledge, resisting the erasure of the sources and lineages that inform our understandings.
[7] “Just” was intended to underscore the casual, and potentially harmful or uncritical, scientific practices that can occur when broader relational or ethical contexts are not taken into account. “Just” emphasizes the subtle, often unexamined domino-effect of actions, and invites readers to critically reflect on their own practices.

long-term, significant impacts. So, for me, it really goes back to the idea of being in relation, not only with the knowledge, but with what that knowledge is producing.

Roxana: This reminds me of a quote I heard recently from Jerry Daniels, Grand Chief of the Southern Chiefs' Organization in Manitoba. I thought what he said really illustrated the importance of relationship and understanding of our different worldviews. He said that reconciliation, from his perspective, is reconciling an Indigenous worldview with the worldviews of Canadians and newcomers because right now, there is a disconnect between these worldviews–particularly when it comes to treaty rights and treaty responsibilities. From an Indigenous perspective, there is respect that is given to the land and the water as they are part of relationships and kin, whereas science typically sees the land and water as a commodity that can be used, extracted and transformed into whatever suits the needs of some. As people living on treaty lands, we should learn and teach about the personhood of the land and water and that we are infringing on their rights as beings when we make chemicals that will pollute them. If we consider this definition of reconciliation, then pollution stands directly in the way of reconciling.

Brooke: I think it is a really important point. If you look at land or water or plants or animals as a commodity, then you treat them, understand them and respect them a certain way – or don't respect them. Alternatively, if you consider these entities as beings that share this space with you, then you have a much different relationship with them than you would to a commodity. And were you to further shift your perspective or understanding to consider these beings as gifting themselves to sustain you, how would that further shift your thinking from a commodity mindset? It brings a much greater respect to that relationship.

We, as humans and scientists, have such great capacity for creation. But with that capacity, are we considering our interconnectedness, our ethical awareness and our responsibility to be in good relation with our environment? Are we minimizing our impacts? Are we operating in sustainable ways? What are we giving back to our environment? Incorporating reciprocity into chemistry, chemistry education and environmental stewardship emphasizes the importance of ethical and sustainable practices. We recognize that our actions have consequences that have the potential to impact not only our environment but also that of future generations, for better or for worse.

> We need to intentionally make and hold space in science for other perspectives and worldviews. And I think there are different ways to think about that, right? You can look to Two-Eyed Seeing and weaving Indigenous and eurocentric Knowledges (Bartlett et al., 2012). You can look to **Two-Row Wampum** and Knowledges that are traveling side-by-side (Hill & Coleman, 2019). Those from other Nations and cultures will have their own teachings that they can bring to the table. We all have our own lived experiences and personal worldviews that can and should contribute to our collective understanding. I believe it is not important that we all have the same teachings or perspectives, but rather that we're making space for all these Knowledges to coexist with respectful understanding of each other.

CONCLUSION

This chapter has explored the multi-faceted dimensions of science education and research. Giving examples from chemistry education, we focused on the often-overlooked areas of ethics, social justice and environmental responsibility. We hoped to have highlighted the critical gaps in current, pedagogical models and the imperative need for a paradigmatic shift.

Drawing upon divergent backgrounds – one rooted in traditional chemistry education and the other in Indigenous Knowledge systems (Absolon, 2022) – we have arrived at a consensus that a reformed approach to science education is essential. Science education needs an integrated curriculum that does not treat ethical considerations, social justice and environmental impact as supplementary elements, but rather as foundational to scientific inquiry. Another important point is the limitations of the current eurocentric approach to science education. Instead, we propose a pluralistic model that accommodates different ways of knowing and alternative paradigms such as biocentrism, [w]holism and ecocentrism. This change includes questioning the fallacy of objectivity in scientific research, and acknowledging that the interpretation of data is inextricably linked to the researcher's own biases, experiences and worldviews. Allowing for these different perspectives enables a student's early introduction to critical thinking and ethical considerations in their educational journey.

Considering the multitude of environmental pollution and justice issues that we face, it is important that we rethink science education to be more [w]holistic, ethically grounded and socially responsible. We contend that such a transformation is not just an academic exercise, but a moral obligation, especially in the context of global challenges that require interdisciplinary and cross-cultural collaboration for sustainable solutions.

REFLECTION QUESTIONS

1. How can educational institutions implement a curriculum that integrates ethics, social justice and environmental considerations from the outset, rather than treating them as supplementary topics? What challenges might they encounter in this process, and how could they be overcome?
2. In what ways can researchers and educators acknowledge and navigate their own biases, positionality and worldviews to conduct more equitable and responsible science? How might this change the landscape of scientific research and its societal impact?
3. How can Western scientific paradigms be reconciled with Indigenous worldviews, especially in the context of environmental stewardship and social justice? What models or frameworks, such as Two-Eyed Seeing or Two-Row Wampum, might facilitate this integration, and what would be the implications for both academic and community-based research?

GLOSSARY

ENVIRONMENTAL STEWARDSHIP is the responsible use and protection of the environment. This can be in the form of limiting harvesting and resource use to sustainable levels, as well as creating protected spaces. The concept of environmental stewardship is embedded in many Indigenous worldviews and treaties that ask us to share the land, take only what we need and leave enough for those who come after us.

EUROCENTRISM centres knowledge and culture in European culture or history, sometimes to the exclusion of a wider view of the world. In its extreme, eurocentrism regards European culture as preeminent.

FOREVER CHEMICALS is a term used for per- and polyfluorinated alkyl substances (PFAS) because of their extreme longevity in the environment. These chemicals contain multiple carbon fluoride bonds, which are the strongest bonds in organic chemistry. This strength means that these chemicals cannot be broken down under normal environmental conditions. Consequently, the use of PFAS in a variety of consumer and industrial products is leading to ever-increasing environmental contamination problems.

POSITIONALITY refers to an individual's lived experiences and social identities (e.g. gender, ethnicity, ability, profession, geographical location, etc.); the combination of these lived experiences and identities shapes how we perceive, understand and engage with the world around us and others. Positionality also shapes our perception of knowledge, perspectives and
learning.

TURTLE ISLAND is the name used by some Indigenous Peoples for North America (and sometimes, more broadly, for Earth). It is a reference to Indigenous creation stories common in communities across North America.

TWO-ROW WAMPUM is the oldest known treaty between some of the inhabitants of Turtle Island (the Haudenosaunee Confederacy) and newly arriving Europeans. The treaty establishes a framework of mutual respect and co-existence while emphasizing the distinctness and separateness of Haudenosaunee and European peoples and their independent affairs. Already extending for a period of more than four centuries, Two-Row Wampum established a friendship that is meant to endure through all the [Earth]planet's[8] natural cycles. [In practice, the ways in which the treaty has been broken are innumerable.][9]

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[8] Many Indigenous Peoples speak of Earth as Mother, affirming a living relationship in which reciprocal responsibilities are upheld. In this worldview, Earth is understood as Kin rather than an object (planet), necessitating the interdependence and accountability that define this relationship.

[9] There can be no reconciliation without truth. When discussing the Two-Row Wampum, acknowledging that the treaty relationship has not always been upheld honours the Treaty and ensures that the responsibilities within this relationship are not lost to future generations.

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