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EDITED BY
Salvatore Micciche',
University of Palermo, Italy

REVIEWED BY
Francesca Soramel,
University of Padua, Italy
Rosaria Bonito,
Osservatorio Astronomico di Palermo (INAF), Italy

*CORRESPONDENCE
Erica Caden,
erica.caden@snolab.ca

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Enhancing equity, diversity, and inclusion in physics: perspectives from North American underground laboratories

Erica Caden[1]*, Samantha Kuula[1] and Rochelle Zens[2]

[1]SNOLAB, Lively, ON, Canada, [2]Sanford Underground Research Facility, Lead, SD, United States

Equity, Diversity, and Inclusion (EDI) are important to drive innovation in many different fields, including particle physics. Underground labs are working on many different fronts to improve EDI in their host countries and within particle physics collaborations. Laboratories can institute policies to protect their staff and make improvements to their facilities to increase accessibility. Laboratories can encourage the scientific collaborations they host to have policies and plans for increasing EDI. SNOLAB and the Sanford Underground Research Facility (SURF) are each supporting their employees and user-bases in different ways. Some examples are targeted outreach, consultation with experimental collaborations on their own policies, EDI training, and Indigenous cultural recognition. These efforts are intended to enhance the equity and inclusion of their communities.

KEYWORDS

underground, physics, diversity, equity, inclusion

1 Introduction

Increasing the Equity, Diversity, and Inclusion (EDI) in any organization improves the output of that organization [1, 2]. For the purpose of this paper, we are operating under the following definitions [3]:

Equity: This ensures everyone has access to the same opportunities to grow, thrive, and do their best work. We recognize that advantages and barriers exist for some groups, and that therefore we do not all start from the same place.

Diversity: This encompasses all the ways that individuals or groups are uniquely different from one another. We embrace a broader definition of diversity that not only includes race, ethnicity, and gender but also age, national origin, religion, disability, sexual orientation, socioeconomic status, education, marital status, language, and other factors that influence our ideas, values, perspectives, and experiences.

Inclusion: This is fostered by creating an environment where any individual or group feels welcomed, respected, valued, and empowered to not only fully participate but also to succeed. We are committed to creating a workplace that respects and embraces the differences of every member of our team.

The importance of EDI has also been recognized by national funding agencies in Canada and the US [4–7]. Our objective is a moving target that needs to adjust to the evolving demographics of our society in a timely way. Host laboratories have many roles to play in improving the EDI culture of particle physics. As a laboratory that operates its entire underground space as a Class-2000 clean room, SNOLAB in Greater Sudbury, Ontario,

Canada has additional EDI challenges and opportunities to support its workforce. Sanford Underground Research Facility (SURF) in Lead, South Dakota, United States has taken a leading role in working with the Indigenous peoples who occupied the land for generations before the mine was built. Both North American laboratories' efforts are detailed here.

2 SNOLAB

SNOLAB is Canada's deep underground research laboratory, located in Vale's Creighton mine near Sudbury, Ontario Canada. It provides an ideal low background environment for the study of extremely rare physical interactions. SNOLAB's science program focuses on astroparticle physics, specifically neutrino and dark matter studies, though its unique location is also well-suited to biology and geology experiments. SNOLAB facilitates world-class research, trains highly qualified personnel, and inspires the next-generation of scientists. It is an expansion of the facilities constructed for the Sudbury Neutrino Observatory (SNO) solar neutrino experiment and has 5,000 m^2 of clean space underground for experiments and supporting infrastructure. A staff of over 140 work to support the science by providing business processes, engineering design, construction, installation, technical, and operational support. SNOLAB research scientists provide expert and local support to the experiments and undertake research in their own right as members of experimental collaborations.

SNOLAB is working to improve EDI in Canada through targeting different aspects of research. Within the field of astroparticle physics, SNOLAB plays a significant role hosting many experiments run by large collaborations of scientists. SNOLAB effects change in these groups as well as its own workforce through coordinated efforts in outreach, leadership, experimental policies, and improving its unique underground environment.

2.1 Outreach

SNOLAB's Education and Outreach Group reaches out to communities that are underrepresented in Canadian physics, including women, Indigenous groups, and the 2SLGBTQI+[1] community. SNOLAB provides master classes on analyzing physics data from the SNO experiment [8] and low-background, high-purity Germanium detectors [9] for the International Summer School for Young Physicists [10] and the Canadian Astroparticle Physics Summer School [11]. These annual schools are for high school and undergraduate students and show what a career in research can look like. SNOLAB provides support to a number of local high school robotics teams including the Wiikwemikoong high school team, First Nations STEM [12]. Specifically, SNOLAB donated equipment from its machine shop to assist their efforts in setting up their workshop space. As part of our public outreach, SNOLAB has partnered with Anishinaabe Akinomaagewin Bemwidoot (Knowledge Carrier) William Morin, to provide free, public planetarium shows at the Doran Planetarium at Laurentian University [13]. These events explore the night sky through traditional sky stories. SNOLAB also is a partner in the TRISEP summer school, a 2-week intensive summer program for graduate students [14]. TRISEP's location rotates between TRIUMF (Canada's accelerator lab), Perimeter Institute (a theoretical physics institute), and SNOLAB.

SNOLAB also presents at local career fairs, providing opportunities to engage with the local community at all levels. SNOLAB coordinates with the local boards of the Professional Engineers of Ontario and Women in Science and Engineering professional societies. SNOLAB also participates in the WISE Science Olympics, aimed at girls 9–12 years old to strengthen their interest in science. Education resources are available on the SNOLAB website, with material aimed at different grade ranges [15]. Since 2017, SNOLAB has hosted a booth in the local 2SLGBTQI + Pride festival. Volunteers explain the science of bubbles and rainbows and share information about the laboratory while showing our support for the community. SNOLAB employees have undergone gender inclusivity training through Safer Spaces [16]; this training improved organizational awareness understanding of why its important to show up and support our gender diverse community.

In 2019, SNOLAB partnered with Digital M'kmaq to host a high impact research experience for a group of Indigenous high school students from Nova Scotia. This facilitated a week of learning about science and research in Sudbury. The visit included a day at SNOLAB and travel to the underground facility followed by science talks [17]. Digital M'kmaq has transitioned to Ulnooweg Education Centre. The SNOLAB Education and Outreach Group has reengaged with this group in 2023 to bring the science of SNOLAB to the students in their programming.

2.2 Experiments

As a host lab for large international collaborative experiments, SNOLAB encourages collaborations to have policies that enhance diversity and inclusion in their own ranks. During the initial formation of an agreement between a new scientific collaboration and the lab, each collaboration must have a formal Code of Conduct that is approved by its scientific board. The Code of Conduct should include a path for escalation of issues, be reviewed regularly by the collaboration board, and shared with the collaboration at all large meetings. This is a good first step for many collaborations, but more can be done [18].

As the conceptual and technical designs of an experiment advances, so too should the plans for increasing EDI within the experimental collaboration. Collaborations are each unique, and the EDI plan should be developed by members who understand their own group dynamics and needs. This can include any number of initiatives and varies depending on the size of the collaboration. Ideas for initiatives can include mentorship programs, junior member board representation, including EDI-focused seminars at collaboration meetings, ensuring broad advertising of hiring

1 The recognized Canadian acronym for those who identify as Two-Spirit, Lesbian, Gay, Bisexual, Transexual, Queer, Intersex, and inclusive of other identities.

announcements, and performing a climate survey, among others. The plan should include measurable goals, and progress can be presented to the lab during design reviews and bi-annual experimental reviews.

2.3 Leadership

SNOLAB has incorporated EDI in its leadership through actions that reach into the structure of the lab. SNOLAB named an EDI officer in 2020, who then led a limited-time task force that developed an action plan [3] to be completed by 2023. Measurable indicators that can be used to assess the impact of action plan are:

- Number of complaints, annual reports, complaint trends and analysis;
- Number of EDI reviews, training sessions, barrier removals, policy and procedure changes;
- Increases/decreases in reporting, results and other representation data trends;
- Feedback from internal and external stakeholders (questionnaires, interviews, focus groups);
- Distinct Staff and User Engagement Surveys.

Data collection of these indicators will be crucial for informed decision making. These data will be collected through the engagement surveys, and will be shared in SNOLAB's annual report when statics are available. With inclusion in mind, SNOLAB supports its staff's personal safety in a number of different ways. EDI is written into policies for the lab staff. These include exempting travel to countries or areas wherein the laws and culture are harmful to people with certain identities. SNOLAB's Young Workers Program is required for all employees under 25 years of age, in both term and indefinite positions. This is to ensure that new workers are aware of all their rights and the safety protections that they should be afforded. SNOLAB has designated a quiet space in its office building, to be used for prayer, reflection, or a personal space for nursing/pumping parents.

All staff are encouraged to share their pronouns in their email signatures. This is a normalizing practice that ensures everyone is addressed in the manner they prefer. SNOLAB created stickers for sharing pronouns on name tags while at conferences.

In 2021, SNOLAB signed the Dimensions Charter. An initiative of the Natural Sciences and Engineering Research Council of Canada, the charter is foundational to the Dimensions pilot program that aims to transform post-secondary research experiences and contributions by achieving greater EDI across Canada's research community. By committing to the charter's principles and implementing actions to achieve the charter outcomes, institutions demonstrate their recognition that improving EDI strengthens our research communities. In turn, these efforts will improve the quality, relevance and impact of research, and the opportunities for the full pool of potential participants [19].

SNOLAB regularly conducts Pay Equity Assessments. These are a method of evaluating pay rates within an organization and assessing differences in relative to age, race, gender, seniority, among other criteria. Pay equity assessments are done to remove the effects of unintended biases and create a more equitable workplace.

Having implemented the action plan, in 2023 the task force was replaced with a standing committee. The standing committee membership will be selected to be more representative of the SNOLAB community and user base. EDI continues to be a pillar in the SNOLAB 2023–2029 Strategic Plan. SNOLAB has embraced and implemented these policies from the bottom-up, with support from the top-down, and worked to create a safe and inclusive workplace [20, 21].

2.4 Underground facility

SNOLAB operates its entire 5,000 m^2 underground facility as a Class-2000 clean room, inside an active mine site [22]. This obligates different requirements than other underground facilities might have in terms of the preparation that staff and users undergo to access the lab space. All persons entering SNOLAB underground must have a shower, to remove any dust from the travel through the mine drift. Currently the showering facilities are gendered, and SNOLAB supports all staff and users to choose the change room they feel most comfortable in.

There are plans to renovate the underground space to include a universal shower, for accommodating those who might not feel comfortable showering in a gendered space. This shower already exists in the surface building after recent renovations. SNOLAB is sourcing a mobile quiet space for providing a prayer/pumping space underground as well. The washrooms underground are all "universal", meaning that each one can be used by a person of any gender-identity.

2.5 Mural

In April 2023, SNOLAB worked with William Morin on the creation of a large mural in the lobby of the surface building. This mural, titled "Agaashiinyi: It is Small" is shown in Figure 1. The piece interweaves Indigenous and western knowledge into a cohesive and inspiring work explaining astronomy and particle physics that every person experiences when they enter the building [23].

The mural design begins with the Dream Catcher at the centre, where the spiral paths of the neutrinos emerge from within, out in all directions. For the Anishinaabek, the creation story begins among the stars. The North Star, also called the going-home star or Kiiwe-di-nong, is highlighted within the sky. The mural reminds us of our place in the world by depicting the Milky Way (Jiibay Miikana), the Northern Lights (Waasinoode), and the Boreal Forest (M'tigwaaki) which is the ancestral home of the Anishinaabek, the Ojibwa, Odawa, Potawatami, Algonquin, Cree, and Saulteaux [24]. The bottom right corner has the string of seven strawberries (Ode-min), to reflect many Anishinaabek teachings: the seven Grandfather teachings, women's berry fasting teachings, and our relationship and connection with all plant life [25]. On the outer edge of the Dream Catcher circle are the four colours of the medicine wheel: yellow, red, black, and white. Anishinabek knowledge tells us that these colours represent many things: the sacred medicines, the seasons, and the prophecy that all colours of people would one day inhabit Turtle Island (North America) [26]. For SNOLAB, this means diversity: people, voices, ideas, and world views are all represented—making for better science.

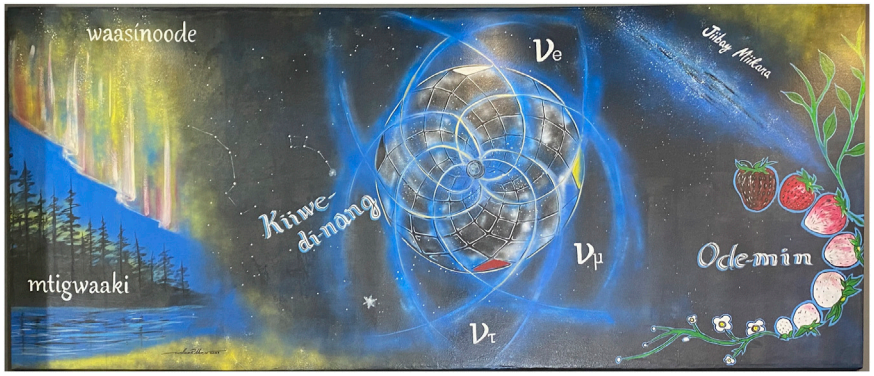

FIGURE 1
Mural by William Morin in the SNOLAB lobby. The themes include neutrinos, the stars, the northern nights, the local forest, the medicine wheel, strawberry teachings, and Anishinaabek names for these concepts. More information can be found in Section 2.5.

3 SURF

The Sanford Underground Research Facility (SURF) is governed by the South Dakota Science and Technology Authority (SDSTA) and hosts world-leading science experiments in a range of disciplines including physics, geology, biology, and engineering. SURF provides significant depth and rock stability—a near-perfect environment for experiments that need to escape the constant bombardment of cosmic radiation, which can interfere with the detection of rare physics events [27].

The history of SURF is complex and has shaped the SDSTA's approach to diversity, equity, and inclusion efforts. SURF is located at the site of the former Homestake Gold Mine in Lead, South Dakota. Homestake was established in 1877, when miners were drawn into the region after General George Armstrong Custer proclaimed the region to be laden with gold [28]. At the time, numerous Indigenous groups lived in and around the Black Hills, an area still held sacred by numerous Tribal Nations in the region today. Thereafter, mining and the desire to homestead led to incredible land loss for Indigenous peoples in the region. From 1851 to 1889, Indigenous groups in the area went from free reign over their traditional homelands to forced removal to the reservation boundaries we know today. Homestake officially closed in 2002, and by 2006 the mine transitioned into an underground research facility [27].

3.1 IDEA office

In light of this history and the need to build a welcoming environment at SURF, the Inclusion, Diversity, Equity and Access (IDEA) Office was formally established in January 2021. The SURF IDEA Office works to:

- create a sense of belonging among SDSTA employees;
- build relationships with under-served communities in South Dakota, with a focus on tribal communities;
- and ensure all visitors to SURF feel welcome.

There are several initiatives at SURF that aim to address the area's history with Indigenous populations, including communication with the Tribal Nations surrounding SURF, a Cultural Advisory Committee, Čhaŋgléška Wakȟáŋ: the ethnobotanical garden at SURF, and the Star Knowledge Working Group.

While the IDEA Office was not established until 2021, cultural efforts at SURF have been a priority since the beginning. The transition from the Homestake Gold Mine to the establishment of SURF led to extensive underground excavation. During this transition, SURF leadership recognized the importance of communicating these developments to regional tribes. In 2010, SURF created a culture and diversity position to lead these efforts and established the Cultural Advisory Committee (CAC), see Section 3.2.

3.2 Cultural advisory committee

The SURF CAC promotes cultural awareness at SURF and advises the SDSTA on topics such as diversity in the workforce, outreach to tribal communities, and creating cultural awareness opportunities for SDSTA staff and the surrounding community. The CAC's recommendations assist the SDSTA Board and key stakeholders in developing cultural awareness activities, including education and outreach programming and recruitment of underrepresented groups. The CAC is comprised of tribal members, educators, and community members and leaders [29]. Two recommendations from the CAC have had a particularly strong impact on the work of the IDEA Office, as outlined in Secs. 3.3 and 3.4.

3.3 Čhaŋgléška Wakȟáŋ

One recommendation was the creation of Čhaŋgléška Wakȟáŋ, the ethnobotanical garden at SURF. The garden's Lakota name roughly translates to "sacred hoop or circle." The garden was originally suggested by a CAC member who is an ethnobotanist and an enrolled member of the Cheyenne River Sioux Tribe. Located on a hilltop meadow at SURF, Čhaŋgléška Wakȟáŋ will serve as a space that inspires connection and collaboration across worldviews and differences. The garden will function as a physical reminder of the cultural significance of this region and SURF's pledge to build meaningful relationships with community partners. The garden will encourage its visitors to slow down and recognize the importance of stewarding the environment along with

FIGURE 2
An imange of Čhaŋgléška Wakȟáŋ, a sacred ethnobotanical garden on SURF grounds. More information can be found in Section 3.3.

relationships that are built in and around SURF. Construction of Čhaŋgléška Wakȟáŋ was completed in the fall of 2023, and is shown in Figure 2. Initial programming for the garden is being developed, and opportunities include presentations from tribal organizations and leaders, opportunities for community gardeners to connect, and teacher professional development on topics related to reclamation [30].

3.4 Star knowledge working group

The CAC also recommended the creation of a working group that would create public learning opportunities to highlight connections between the science conducted at SURF and indigenous ways of knowing. As a result of this recommendation, the Star Knowledge Working Group was formed in 2022. The Group examines topics such as Native star knowledge and understandings of the beginning of the Universe, looking for connections to the science taking place at SURF. Once developed, the Group will use these connections to share cultural and scientific concepts with SURF's internal and external communities.

Currently, the Group meets four times per year and is comprised of staff from the SURF IDEA Office, Education and Outreach Department, the Sanford Lab Homestake Visitor Center, and the Science Department. The Group is currently working to address several recommendations of the CAC, including the creation of programming that highlights cross-cultural attempts to understand the origins of the Universe in order to in order to strengthen relationships with the communities surrounding SURF. Successful programming will require SURF staff and scientists to work collaboratively alongside Indigenous elders and culture bearers to highlight traditional knowledge and draw connections to current research being conducted at SURF.

4 Summary and outlook

Implementing successful EDI programs at any organization, including underground laboratories, takes persistence and the willingness to change and adapt as necessary. Organizations with strong EDI programs ensure that everyone is included and can see their identities reflected in the space. Practitioners must pay special attention to their surrounding communities as well as the communities they serve—researchers, employees, contractors, and others. Incorporating cultural connections through artwork, shared spaces, and other venues can create space for productive dialogue for both scientific connections and belonging.

Demonstrating better outcomes by building more diverse teams is an important tool for top-level management to understand to ensure increased success. Development of policies and implementation of programming to promote cross-cultural learning are two complementary approaches to bolstering equity, diversity and inclusion. Both SNOLAB and SURF have made important steps to implement these approaches in their own organizations. The future work of both organizations will include evaluating and publishing the results of climate surveys and other feedback mechanisms to re-inform our work and update our actions accordingly. The people of underground laboratories, like any organization, are constantly changing and as a result EDI practitioners must be constantly prepared for adaptation.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Author contributions

EC: Conceptualization, Resources, Writing–original draft, Writing–review and editing. SK: Conceptualization, Resources, Writing–review and editing. RZ: Conceptualization, Resources, Writing–original draft, Writing–review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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