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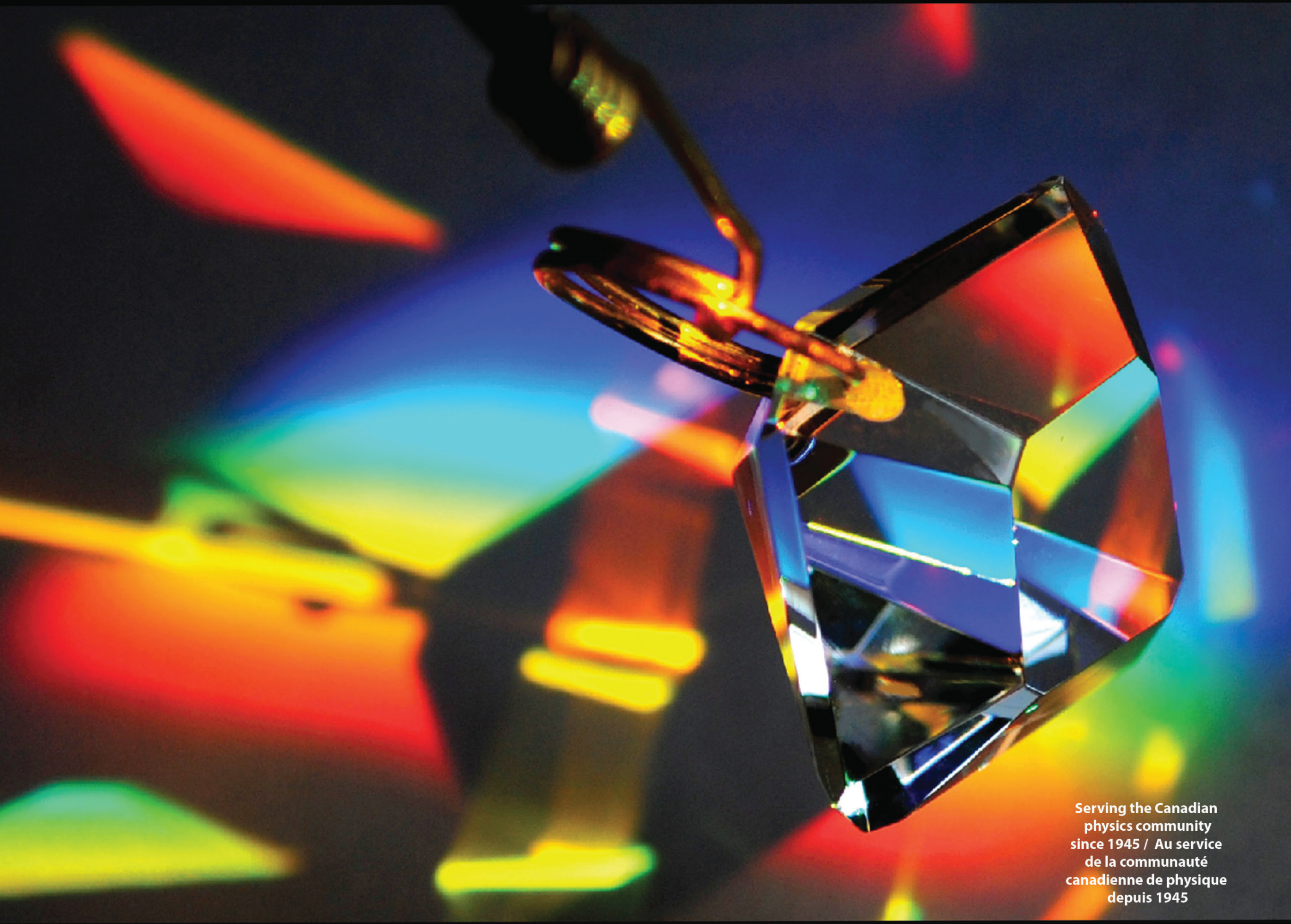

INCLUSION FOR EXCELLENCE / INCLUSION POUR L'EXCELLENCE :

THE PHYSICS COMMUNITY IN CANADA / LA COMMUNAUTÉ DE PHYSIQUE AU CANADA

Canadian Association of Physicists / Association canadienne des physiciens et physiciennes

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PHYSICS IN CANADA
LA PHYSIQUE AU CANADA
Volume 77 No. 1 (2021)

FEATURE ARTICLES
ARTICLES DE FOND

Cover / Couverture:

Like a prism dispersing light into its component colors, this issue is a medium for diverse members of our community to illumine their manifold perspectives.

À la manière d'un prisme qui disperse la lumière en toutes ses couleurs, ce numéro spécial est un moyen pour les divers membres de notre communauté d'illuminer leurs nombreuses perspectives.

Source: "Wednesday's Symphony of Light and Colour". Image provided by user MrPrism on Imgur.com

Source : "La symphonie de lumière et de couleur du mercredi". Image fournie par l'utilisateur MrPrism sur Imgur.com

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Feature Articles
Articles de fond

Canadian Association of Physicists (CAP)
Association canadienne des physiciens et physiciennes (ACP)

The Canadian Association of Physicists was founded in 1945 as a non-profit association representing the interests of Canadian physicists. The CAP is a broadly-based national network of physicists working in Canadian educational, industrial, and research settings. We are a strong and effective advocacy group for support of, and excellence in, physics research and education. We represent the voice of Canadian physicists to government, granting agencies, and many international scientific societies. We are an enthusiastic sponsor of events and activities promoting Canadian physics and physicists, including the CAP's annual congress and national physics journal. We are proud to offer and continually enhance our web site as a key resource for individuals pursuing careers in physics and physics education. Details of the many activities of the Association can be found at http://www.cap.ca. Membership application forms are also available in the membership section of that website.

L'Association canadienne des physiciens et physiciennes a été fondée en 1946 comme une association à but non-lucratif représentant les intérêts des physicien(ne)s canadien(ne)s. L'ACP est un vaste regroupement de physiciens et de physiciennes oeuvrant dans les milieux canadiens de l'éducation, de l'industrie et de la recherche. Nous constituons un groupe de pression solide et efficace, ayant pour objectif le soutien de la recherche et de l'éducation en physique, et leur excellence. Nous sommes le porte-parole des physicien(ne)s canadien(ne)s auprès du gouvernement, des organismes subventionnaires et auprès de plusieurs sociétés scientifiques internationales. Nous nous faisons le promoteur enthousiaste d'événements et d'activités mettant à l'avant-scène la physique et les physicien(ne)s canadien(ne)s, en particulier le congrès annuel et la revue de l'Association. Nous sommes fiers d'offrir et de développer continuellement notre site Web pour en faire une ressource clé pour ceux qui poursuivent leur carrière en physique et dans l'enseignement de la physique. Vous pouvez trouver les renseignements concernant les nombreuses activités de l'ACP à http://www.cap.ca. Les formulaires d'adhésion sont aussi disponibles dans la rubrique « Adhésion » sur ce site.

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Foreword - Inclusion for Excellence; The Physics Community in Canada

The physics community in Canada is well-known for world-class research, top educational programs, and innovative outreach initiatives. It is made up of thousands of brilliant students and trainees, researchers, teachers, professors, private sector professionals, and civil servants. Many physicists' lives were significantly disrupted by the impacts of the Covid-19 pandemic and subsequent restrictions over the past three years. It has become clear, however, that these impacts were not distributed evenly; rather, they exacerbated existing inequalities and injustices, following the lines of historic and ongoing discrimination. These inequalities and injustices were further highlighted by the Black Lives Matter protests across the world in the summer of 2020 in response to the murder of George Floyd, leading to the academic Strike for Black Lives (#ShutDownSTEM Day) in which many Canadian physicists participated.

The situation has provided an opportunity for a closer examination of the larger state of equity, diversity, and inclusion (EDI) within the physics community in Canada. This special issue of *Physics in Canada* will highlight the experiences of historically underrepresented groups in physics, discuss current challenges, and explore paths towards building a stronger and more inclusive community.

We all benefit when our community is thriving. COVID-19 has taught us that "we can't win unless we all win." If we leave people behind, it's going to impact our individual quality of life. Countless studies have reinforced the connection between diversity and scientific excellence - it empowers greater innovation, creative problem-solving, critical thinking, and teamwork. However, diversity is not enough. In order to foster an environment where physicists have a wide range of backgrounds, personal experiences, and perspectives, we must first shift our focus to ensuring that the environment itself is inclusive. This is hard work. It requires actively dismantling systems and structures that were historically used for the explicit exclusion of various groups, while simultaneously creating new pathways, supports, and programs that aim to remove as many barriers to entry as possible. We all have a role to play in this effort, and even making small changes to our daily lives can have a significant impact. We hope that the articles featured in this special issue will help our readers obtain a deeper understanding of the interconnectedness of our history and current structural inequities within physics, and gain new insights and tools that they can implement to make their classrooms, labs, and offices more inclusive.

Physics in Canada traditionally focusses on the research activities of the Canadian Association of Physicists and issues of importance to the Canadian physics community and, as such, discussions around the past and future of EDI in our community fit perfectly into the mandate of the magazine. As a result, we feature personal testimonials and opinion articles for the first time. The issue begins with an article on the "Decolonizing Light" project, where authors explore approaches to the decolonization of physics within the Canadian curriculum and physics community at large. We then present a series of articles offering BIPOC perspectives and analysis of the importance of visibility, data, and mentorship. The following section focuses on gender, lived experiences, and the power of language and images. The issue closes with a selection of articles discussing intersectionality, and how these topics are interwoven into our daily lives.

One of the most important pillars of physics is the scientific method; the circular nature of hypotheses, theories, and measurements allows us to better understand the world around us. In this spirit, we established a project to help us better understand the current state of the physics community in Canada. Fall 2020 saw the opening of the first Canada-wide Equity, Diversity, and Inclusion in physics survey. The CanPhysCounts survey aimed to answer three main questions: who are the physicists in Canada, what do they do, and what are their experiences within the physics community? The survey received over three thousand responses, and we are analyzing the data in partnership with the Laurier Centre for Women in Science (WinS). This issue will feature a report on preliminary

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data, with the full analysis being published in an academic journal.

It is crucial that this survey be continued in future years, not only to quantify the demographics and experiences of physicists in Canada, but also to offer reliable statistics to track our progress. Canadian researchers have outlined many barriers to inclusion within science at large — unconscious and implicit bias, affinity bias, white normativity, tokenism, equity tax, and countless other factors that impact academic and career decisions. Many institutions have published reports on the persistent lack of diversity, wage gaps, precarious work, and discriminatory practices and policies. Large-scale changes, however, are slow or non-existent. A key finding of the 2019 Universities Canada annual report on Equity, Diversity, and Inclusion was that one major barrier to improvement was a lack of data. In short: we can't change what we can't measure. The CanPhysCounts survey is a substantial step forward on this front, and will provide guidance to our community as it implements new practices and analyzes their impact.

You will notice that this special issue contains a series of mini-profiles, where leaders in our community provide their answers to the simple question: "Why does the physics community in Canada need to be inclusive in order to be excellent?" We hope that you find their answers inspiring, and as you read the issue, will be able to form your own response in turn. Together, we can build a stronger community for future generations of physicists in Canada.

Anastasia Smolina, University of Toronto and
Kevin Hewitt, Dalhousie University
Guest Editors, *Physics in Canada*

Comments of readers on this Editorial are more than welcome.

Préface - Inclusion pour l'excellence; La communauté de physique au Canada

La communauté des physiciens au Canada est réputée pour ses recherches de classe mondiale, ses programmes éducatifs de haut niveau et ses initiatives de sensibilisation novatrices. Elle est composée de milliers de brillants étudiants et stagiaires, de chercheurs, d'enseignants, de professeurs, de professionnels du secteur privé et de fonctionnaires. La vie de nombreux physiciens a été considérablement perturbée par les répercussions de la pandémie de Covid-19 et les restrictions qui en ont découlé au cours de l'année et demie écoulée. Il est cependant devenu évident que ces impacts n'ont pas été distribués de manière égale ; ils ont plutôt exacerbé les inégalités et les injustices existantes, suivant les lignes de la discrimination historique et continue. Ces inégalités et injustices ont été mises en évidence par les manifestations Black Lives Matter à travers le monde à l'été 2020 en réponse au meurtre de George Floyd, ce qui a conduit à la grève universitaire pour les vies noires (#ShutDownSTEM Day) à laquelle de nombreux physiciens canadiens ont participé.

Cette situation a été l'occasion d'examiner de plus près l'état général de l'équité, de la diversité et de l'inclusion (EDI) au sein de la communauté des physiciens au Canada. Ce numéro spécial de *La Physique au Canada* mettra en lumière les expériences des groupes historiquement sous-représentés en physique, discutera des défis actuels et explorera des pistes pour construire une communauté plus forte et plus inclusive.

Nous sommes tous gagnants lorsque notre communauté est florissante. COVID-19 nous a appris que "nous ne pouvons pas gagner si nous ne gagnons pas tous". Si nous laissons des gens de côté, cela aura un impact sur notre qualité de vie individuelle - nous sommes tous interconnectés. D'innombrables études ont renforcé le lien entre la diversité et l'excellence scientifique : elle favorise l'innovation, la résolution créative des problèmes, la pensée critique et le travail d'équipe. Toutefois, la diversité ne suffit pas. Pour favoriser un environnement dans lequel les physiciens ont un large éventail d'antécédents, d'expériences personnelles et de perspectives, nous devons d'abord veiller à ce que l'environnement lui-même soit inclusif. C'est un travail difficile. Il faut démanteler activement les systèmes et les structures qui ont été historiquement utilisés pour exclure explicitement divers groupes, tout en créant simultanément de nouvelles voies, de nouveaux soutiens et de nouveaux programmes visant à supprimer le plus grand nombre possible d'obstacles à l'entrée. Nous avons tous un rôle à jouer dans cet effort, et même de petits changements dans notre vie quotidienne peuvent avoir un impact significatif. Nous espérons que les articles présentés dans ce numéro spécial aideront nos lecteurs à mieux comprendre l'interconnexion de notre histoire et des inégalités structurelles actuelles en physique, et à acquérir de nouvelles idées et de nouveaux outils qu'ils pourront mettre en œuvre pour rendre leurs salles de classe, leurs laboratoires et leurs bureaux plus inclusifs.

La Physique au Canada se concentre traditionnellement sur les activités de recherche de l'Association canadienne des physiciens et physiciennes et sur les questions d'importance pour la communauté physique canadienne. Les discussions sur le passé et l'avenir de l'EDI dans notre communauté s'inscrivent donc parfaitement dans le mandat (objectif) du magazine. Nous sommes heureux de pouvoir mettre en lumière les expériences actuelles des groupes sous-représentés dans ce numéro. Ainsi, nous présentons pour la première fois des témoignages personnels et des articles d'opinion. Le numéro commence par un article sur le projet "Décoloniser la lumière", dans lequel les auteurs explorent les approches de la décolonisation de la physique au sein du programme d'études canadien et de la communauté des physiciens en général. Nous présentons ensuite une série d'articles offrant les perspectives et l'analyse des BIPOC sur l'importance de la visibilité, des données et du mentorat. La section suivante se concentre sur le genre, les expériences vécues et le pouvoir du langage et des images. Le numéro se termine par une sélection d'articles traitant de l'intersectionnalité et de la façon dont ces sujets sont imbriqués dans notre vie quotidienne.

L'un des piliers les plus importants de la physique est la méthode scientifique ; la nature circulaire des hypothèses, des théories et des mesures nous permet de mieux comprendre le monde qui nous entoure. Dans cet esprit, nous avons établi un projet pour nous aider à mieux comprendre l'état actuel de la communauté des physiciens au Canada. L'automne 2020 a vu l'ouverture du premier sondage pancanadien sur l'équité, la diversité et l'inclusion en physique. Le sondage CanPhysCounts visait à répondre à trois questions principales : qui sont les physiciens au Canada, que font-ils et quelles sont leurs expériences au sein de la communauté des physiciens ? Le sondage a reçu plus de trois mille réponses, et nous analysons les données en partenariat avec le Laurier Centre for Women in Science (WinS). Ce numéro présentera un rapport sur les données préliminaires, l'analyse complète étant publiée dans une revue universitaire.

Il est crucial de poursuivre ce sondage dans les années à venir, non seulement pour quantifier les données démographiques et les expériences des physiciens au Canada, mais aussi pour offrir des statistiques fiables permettant de suivre nos progrès. Les chercheurs canadiens ont mis en évidence de nombreux obstacles à l'inclusion au sein de la science en général - les préjugés inconscients et implicites, les préjugés d'affinité, la normativité blanche, le tokenisme, l'impôt sur l'équité, et d'innombrables autres facteurs qui ont un impact sur les décisions universitaires et de carrière. De nombreuses institutions ont publié des rapports sur le manque persistant de diversité, les écarts de salaire, le travail précaire et les pratiques et politiques discriminatoires. Les changements à grande échelle sont toutefois lents ou inexistants. L'une des principales conclusions du rapport annuel 2019 d'Universités Canada sur l'équité, la diversité et l'inclusion était qu'un des principaux obstacles à l'amélioration était le manque de données. En bref : on ne peut pas changer ce que l'on ne peut pas mesurer. Le sondage CanPhysCounts est un pas en avant substantiel sur ce front, et fournira des conseils à notre communauté alors qu'elle met en œuvre de nouvelles pratiques et analyse leur impact.

Vous remarquerez que ce numéro spécial contient une série de mini-profils, dans lesquels des leaders de notre communauté répondent à une question simple : "Pourquoi la communauté des physiciens au Canada doit-elle être inclusive pour être excellente ?". Nous espérons que leurs réponses vous inspireront et qu'en lisant ce numéro, vous serez en mesure de formuler votre propre réponse à votre tour. Ensemble, nous pouvons bâtir une communauté plus forte pour les futures générations de physiciens au Canada.

Anastasia Smolina, Université de Toronto et
Kevin Hewitt, Université Dalhousie
Rédacteurs invités, *La Physique au Canada*

Les commentaires des lecteurs sur cet éditorial sont toujours les bienvenus.
NOTE: Le genre masculin n'a été utilisé que pour alléger le texte.

Decolonizing Light: A Project Exploring Ways to Decolonize Physics

by Ingo Salzmann, Louellyn White, Donna Kahérakwas Goodleaf, and Tanja Tajmel

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In 2018, the Government of Canada established *The New Frontiers in Research Fund* (NFRF) to support high-risk, high-reward and interdisciplinary research. In that framework, we, as a group of non-Indigenous and Indigenous scholars working in fields as different as Physics, First Peoples Studies, Decolonizing Curriculum and Pedagogy, as well as Science and Technology Studies, united to find common ground to explore the decolonization of physics. Here, we outline our motivation, our project rationale and concrete plans underlying our NFRF-funded project *Decolonizing Light — Tracing and Countering Colonialism in Contemporary Physics*, which we will pursue during the next three years.

Decolonization — Why physics, why light?

The aim of our project is exploring approaches to decolonize physics, of both its narratives and contemporary research.[1] We decided to focus on physics, as this discipline plays a special role in the field of science due to its unique scientific authority. Physics is commonly regarded as the "most objective" and the "hardest" science [2], it fundamentally defines scientific key concepts such as energy, matter, force, light, space and time, for all the other sciences. It is the narrative of physics as objective and as socially independent [3] that constitutes and stabilizes its knowledge authority in relation to all other knowledge systems.[2] For our purpose, it is important to understand *physics as a social field* rather than as "pure knowledge" independent from social values and decisions. Physics is more than the laws that describe and predict natural phenomena: it is the overarching field of work with its societal dimension, its history, and the circumstances and purposes of physical knowledge production. The opportunity to participate in producing such scientific knowledge as well as the purposes and benefits of this knowledge are framed by social power relations, by politics, and also by colonialism. This perspective is important because by regarding science as disconnected from society and from its colonial history, colonialism is being reproduced. This is the way in which we regard physics as colonial, and it is based on this notion that we explore approaches to *decolonize physics*.[3]

1. In our understanding of *decolonization,* we follow Linda Tuhiwai Smith: "Decolonization is a process which engages with imperialism and colonialism at multiple levels. For researchers, one of those levels is concerned with having a more critical understanding of the underlying assumptions, motivations and values which inform research practices." [1, p. 21]
2. At this point, we understand *knowledge systems* broadly and do not follow one single definition, as "defining parameters of knowledge systems mirror the disciplinary and political agendas that influence scholars' points of view and methods of analysis". [4, p. 17]

In our project we decided to exemplarily focus on light (rather than on optics, as optics is a physical field and narrows down the concept of light and what can be said about it), because light is ubiquitous in every society, language and culture. In everyday life, light is a key element that defines familiar aspects like color and warmth. In physics, light is exploited as the primary carrier of information about nature (*e.g.*, in astronomy), used as the primary probe for the fundamental properties of matter (*e.g.*, in spectroscopy), or generated in billion-dollar synchrotron radiation centres — prestigious large-scale research facilities at the forefront of contemporary physics research (such as the Canadian Light Source in Saskatchewan located on Treaty 6 Territory and the Traditional Homeland of the Métis). The purpose of our project is not to find new or better explanations of light; we are not seeking to improve scientific 'truth'. Rather, our project initiatives are motivated by the marginalization of women, Black people, and Indigenous peoples [5], particularly in physics, as it is documented by the statistics of the American Institute of Physics [6].[4] We regard marginalization as a key problem for social equity as well as for scientific quality. Furthermore, we regard scientific knowledge that reproduces bias and colonial power relations as non-acceptable, as stated in the Declaration for science education as human right [7]. In line with Canadian efforts to address reconciliation, universities such as Concordia have embarked on a comprehensive plan to decolonize curriculum, research and pedagogy across all academic units; this includes to increase the presence of Indigenous and Black students, faculty and staff on all levels. Our project is situated in this social, political and historical context.

3. For a discussion on definitions of *colonialism* see Ref. [1, p. 21f].
4. Note that intersectional effects such as, *e.g.*, gender AND race, are not considered in these statistics.

Possible decolonizing approaches in physics comprise purposefully training university students from marginalized and racialized groups in physics (*e.g.*, by offering well-funded positions to Indigenous and Black graduate students), initiating collaborations with Black (*e.g.*, Montreal's Haitian community) and Indigenous communities in scientific projects, and seeking conversations with Indigenous Knowledge Keepers about their cultural (philosophical as well as practical-empirical) knowledges to include them in the curriculum. In general, scientists and science teachers aim to increase scientific knowledge and scientific literacy of people. In our view, this includes augmenting studying physics by examining ethical frameworks and historical contexts which ask to whose benefits and on whose costs scientific progress has been made. This is the essence of decolonizing physics, a process based on dialogue which we believe to represent a rewarding approach for all.

DECOLONIZING APPROACHES

Our project consists of two complementary parts which inform each other and are mutually connected through the individual expertise in the research team and our own processes of building relationship. The first part (left column in Fig. 1) focuses on Indigenous Knowledge(s) (IK) and education, where we aim to revitalize IK and bring them to academic attention. This includes developing courses together with Indigenous scholars and Knowledge Keepers in which students approach questions from different or culturally diverse perspectives, as well as de-centering Eurocentric Western science through decolonizing curriculum in ways that elevate Indigenous scientific and intellectual contributions and develop new narratives.

The second part (right column in Fig. 1) focuses on physics and Western/Eurocentric science. There, we aim to critically investigate if and how physics itself has contributed and still contributes to colonialism. We investigate its potential colonial history, its values and underlying decision-making processes and aim to identify "blind spots", the non-knowing or lack of knowledge with regards to the role that science played in the context of colonization (see Sec. III). Finally, we investigate strategies of empowering students and Indigenous communities through scientific training and increasing Indigenous scientific literacy for the purpose of self-governance and participation in scientific research and aim to implement these strategies in our project initiatives.

In the following sections (labelled by the respective authors' initials IS, LW, DG, TT), we write about the project from our diverse perspectives and backgrounds, working together on common grounds to contribute to the goal of making academic education acceptable and accessible for all.

I. DECOLONIZING CURRICULA (DG)

Higher education systems in Canada have a history of perpetuating Eurocentric/Western canons of thought as the 'normative discourse' across all academic fields of study and continue to play a key role in promoting the colonization of Indigenous peoples. Canada's Residential schools — and by extension university systems — set the groundwork to perpetuate on-going Eurocentric educational policies and practices designed to diminish and undermine Indigenous epistemologies, languages, histories and cultures while imposing assimilative frameworks and practices on Indigenous students [8-11]. The impacts of these institutional racist policies and practices has led many Indigenous students to drop out of school [12]. The Truth and Reconciliation Commission of Canada released a national report [13] which contains 94 Calls to Action calling upon all Canadian societal institutions inclusive of higher education systems to address the legacy of Canada's historical and on-going assimilative and genocidal policies and practices towards Indigenous Peoples. In response to these Calls to Actions, universities across Canada have embarked on a path of 'decolonizing and Indigenizing' the academy to address on-going institutional racism that is pervasive in university systems across Canada [14,15].

What does *decolonizing the university system* mean? It requires the act of unpacking and examining, through critical discourse and analysis, the history and contemporary lived experiences of colonization and its impacts on Indigenous peoples. It requires a critical examination of patriarchy, racism, and institutional policies and practices that privilege Eurocentric canons of knowledge systems, to the exclusion of Indigenous peoples' diverse

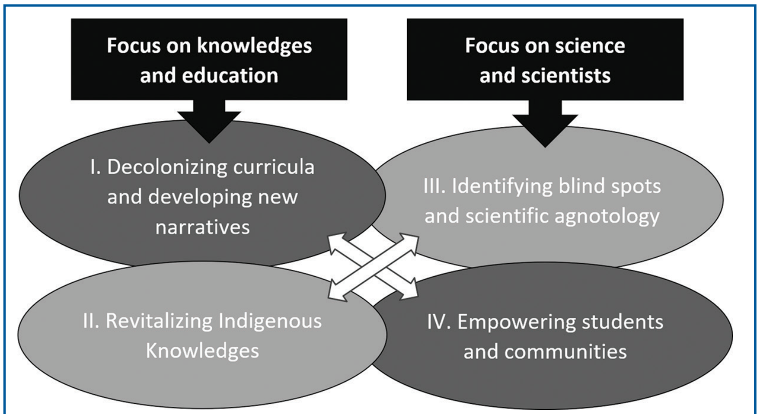
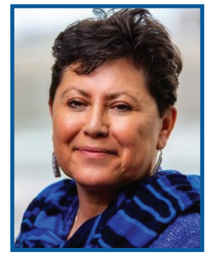


Fig. 1 The two main parts of the project (vertical columns) and the four decolonizing approaches (I … IV) pursued.



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intellectual, agricultural, technological, scientific, cultural, research, and pedagogical knowledge systems, and practices across all academic fields of study [10,16]. It means opening up institutional spaces where Indigenous faculty and settler faculty actively engage as co-constructors in de-centering Eurocentric fields of study and re-centering and validating Indigenous peoples' diverse epistemologies, theories, worldviews, pedagogical practices and research methods across all academic disciplines.

On the faculty level, it requires non-Indigenous settler scholars and scientists to move out of their comfort zone and actively engage in critical self-reflection, analysis and discourse about their role as educators, examining their underlying assumptions, perceptions, biases and belief systems they have about Indigenous peoples. It requires divesting from perpetuating the Eurocentric-'normative discourses' and asking oneself: Whose voices/histories/perspectives are missing in course syllabi? What do I know about the history of the local Indigenous peoples and the territory the university is built on? What pedagogical methods and practices can I use to validate Indigenous students' voices, histories and perspectives in the classroom?

Decolonizing the academy is important because it empowers Indigenous students in their own identities while enriching the educational experiences of all students by providing a better understanding about the history and impacts of colonization, as well as Indigenous peoples' diverse histories, worldviews and contemporary lived experiences. Decolonizing the academia sets a path for all university stakeholders to embark on a path of co-constructing knowledge with Indigenous peoples and communities, while creating a better future for all that values Indigenous ways of knowing.

II. REVITALIZING INDIGENOUS KNOWLEDGE(S) (LW)

As our work aims to center and bring IK to academic attention, we must first understand what it means — which may seem elusive to some, due to the fact that there is no one definition of IK as it reflects the diversity of Indigenous peoples, cultures, and language. IK is also very personal to the individual knowledge holder. Mi'kmaq scholar, Marie Battiste and James Youngblood Henderson state that Indigenous knowledge "cannot be separated from the bearer to be codified into a definition" [17, p. 36]. It is important to understand that IK is, at its core, based on relationality. Battiste and Youngblood define IK as embodying the relations between humans and all living beings and spirits [17]. Tewa scholar, Gregory Cajete elaborates to include relationships to all forces and forms including celestial bodies [18]. These connections form the basis of maintaining social, economic, and diplomatic relationships among human beings. Indigenous worldviews and therefore IK, come from this place of intimate knowledge and understanding of relationality. IK has been and continues to ensure the survival of Indigenous peoples and the world they inhabit and informs decisions about day to day life. UNESCO recognizes the legitimacy and validity of IK as "integral to a cultural complex that also encompasses language, systems of classification, resource use practices, social interactions, ritual and spirituality. These unique ways of knowing are important facets of the world's cultural diversity and provide a foundation for locally-appropriate sustainable development" [19].

However, IK has largely been ignored, disregarded, disrespected, and delegitimized throughout the history of academic institutions and among Western scientists in particular, who often cling to myopic views of the world in which they see themselves as superior [1,17,20]. This serves to "silence, erase, appropriate, dominate, own, and oppress that which it encounters in the world — be it people, knowledge systems, or alternate visions of how the world could be" [21, p. 433]. The divergent worldviews of IK and Western science reflect the ongoing tensions with Indigenous peoples and settlers: "The hegemonic function of academic knowledge production makes individualism, competition, commodification and ownership (and its practices of exclusion in the academic everyday) normal, reifying the colonialist project by forcing the ongoing marginalization of Indigenous knowledge's, ways of knowing and scholarship to the peripheries of what is considered valid" [22, p. 54].

Two-Eyed-Seeing

How do we move forward with a project that brings together such divergent fields of study, backgrounds, worldviews, and ways of knowing? It is all about relationality. That is, our collective relations to each other and relations with time, place, and with all living things. A guiding principle to ground ourselves and our project can be found with what Mi'kmaq elder Albert Marshall calls Etuaptmumk or *Two-Eyed Seeing* [23]. When practicing Two Eyed Seeing a natural phenomenon is viewed through two eyes — two worldviews — one based in Indigenous Knowledge, and the other through Western science. The Two-Eyed Seeing approach allows for intercultural collaboration and multiple perspectives. Marshall writes: "It encourages the realization that beneficial outcomes are much more likely in any given situation when we are willing to bring two or more perspectives into play" [24]. By adhering to the principles of Two-Eyed Seeing, we can reach common ground as we strive for the pursuit of knowledge and understanding. Cree elder and star story expert, Wilfred Buck writes in his book, Tipiskawi Kisik: Night Sky Star Stories, "We arrive at knowledge from many different paths. And the more aware we are of other possibilities, the more sensitive we will be to understanding and difference" [25].

IK, grounded in relationality, is an inherent part of the project in that we commit to supporting IK throughout, recognizing the project as a process, and as an organic co-construction of knowledge. With our diverse backgrounds, we are faced with adhering to principles of IK as we develop our relationships with each other while navigating diverging worldviews and ways of knowing, and maintaining respect, integrity, and the pursuit of knowledge for all.

III. IDENTIFYING BLIND SPOTS (TT, IS)

One way to reinforce knowledge authority is to erase or subordinate other knowledge systems and to cultivate an ignorance with regards to other knowledges and knowledge systems. For this kind of cultivation of ignorance and oblivion in the context of colonialism, Londa Schiebinger used the term *agnotology* [26], which we find appropriate to use in the context of our project. Figure 2 illustrates the embeddedness of physics in the academic field and the blind spots, the holes of knowledge, which are part of this field and even contribute with *cultivated not-knowing* to the stability of the sciences. The not-knowing, the ignorance, the agnotology makes the dominant narrative function. For example, in the context of the current global environmental crisis, science is seen as the solution. However, science not only plays a major role in finding solutions to the existential threats of our times such as climate change, migration, and the distribution of the global wealth, but also plays a significant role in causing these problems. Practices and decisions in scientific research therefore determine whether scientific and technological innovation is of benefit not only to the present but also to future generations, not only to a few but to most people. This approach requires a critical attitude and the willingness to critically question the scientific field. Frameworks and methodologies for this purpose are, for example, feminist theory [27], critical race theory [28], and Indigenous science and technology studies [29]. As illustrated in Figure 2,[5] we regard what has been referred to as the "core of knowledge in physics" [30, p. 113] as an inherent part of the *social field of physics*, highlighting that physics knowledge is not independent from the actors, their values and the historical context in which it was generated. Let's elaborate this further for the example of the Planck–Einstein relation $E = h \cdot \upsilon$ describing the energy E of a light quantum, a single wave-particle of light emitted or absorbed; υ is the frequency which determines the color of light, h is the Planck number named after the German physicist Max Planck who lived around 1900 in Berlin. This formula has been found valid and enabled the development of solar panels (absorption) and lasers (emission). Every STEM student is expected to know this relation. In our project, we will not question $E = h \cdot \upsilon$.[6] But we ask: What person was Max Planck? What circumstances enabled him (and others) to discover this relation? How was his work related to colonialism, by whom was he funded? What happened in this time around the world? Why were essentially only white men doing physics research? What knowledge about light was disrupted by colonialism? We consider questions of this kind as part of physics in a holistic sense.

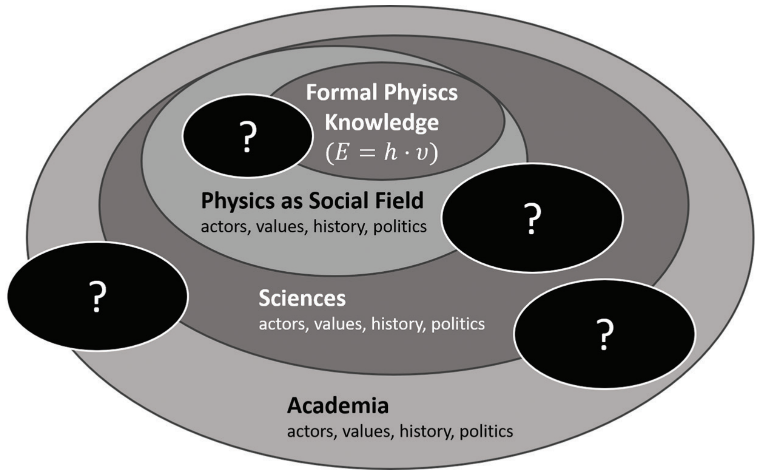

Fig. 2 Physics as a social field embedded in the social fields of the sciences and academia. Black areas illustrate blind spots also contributing to the field.

Decolonizing scientific 'common knowledge'

We as teachers follow curricula which define and decide what students should know, what is considered as 'important' knowledge, as 'common' knowledge and what is expected from a well-educated person, such as a physics graduate, to know. There is consensus that what we (as teachers, as academia) expect is far more than knowing applicable formulae and physical laws. We teach historical physical knowledge even if it does not meet contemporary scientific requirements of 'truth' and correctness. How scientific paradigms (and their changes) are influencing scientific 'truth' is well known from the work of Kuhn and his analysis of science as social institution [31]. We are used to scientific paradigms and their changes. For example, most would agree that every physics student should have heard about Bohr's atomic model, it can be found in logos and as a pin-up in physics departments, it has become the pictogram for the atom and even for physics. We all know that this model is not only wrong but also conceptionally misleading [32]. However, Niels Bohr is still a respected scientist and occupies a key role in physics history (and certainly deserves this role). Another example is Democritus and the atomists. They had the idea that the natural world consists of

5. Like all figures which try to illustrate complex interdependencies, they also bear the risk to oversimplify and even transmit a misunderstanding. However, let us take this figure as an attempt.
6. However, also laws and relations would be interesting to study. As Sandra Harding states, "formal statements require interpretation in order to be meaningful. The results of scientific inquiry can count as results only if scientists can understand what they refer to and mean. Without decisions about their referents and meanings, they cannot be used to make predictions, for example, or to stimulate future research" [27, p. 84].

two different kinds of realities: atoms and void. Atoms are solid with tiny hooks and barbs on their surfaces which enable them to be entangled [33]. Although long since proven to be physically wrong, most physicists would still agree that knowing about the Greek philosophers and their thoughts does not harm physics students and that such knowledge does have its place in academia. *Then, why not knowing and teaching about Indigenous Knowledge systems and philosophies?* They are spatially much nearer to any Canadian student than the Greek philosophers who are distant both physically and temporally (7000 km and 2400 years away) whereas Canadian universities and schools are built on Indigenous territory. With our project we aim to expand the understanding of 'common scientific knowledge' and of 'being educated' by teaching these knowledges, simply because we want our students to be comprehensively educated.

A current example to be examined through a decolonizing lens is the Thirty Meter Telescope (TMT) on Mauna Kea mountain [34]. Apart from its spiritual significance — in Hawaiian cosmology, Mauna Kea is the origin place of the Hawaiian people — the mountain is ecologically fragile [35]. Let us ask, what are the decision processes behind such projects? How are such projects impacting Indigenous realities? What are the values behind these decisions? Whose values are privileged? Decolonizing physics means to train and educate students to ask these questions and to examine them from diverse perspectives. This approach includes research of our own world views, as scientists. To identify "cultivated ignorance", we will study scientists' knowledge of and experiences with colonialism, and investigate textbooks and physics curricula, with which we hope to identify relevant blind spots and fill them with critical knowledge.[7]

IV. EMPOWERMENT (IS, TT)

As a further decolonizing approach, we will pursue training of community members and students to use science for their purposes and to follow research questions that are important for them. We regard situatedness as an important aspect in decolonizing the sciences: for our project, which is situated in the Canadian academic context, this means to elevate knowledges of the cultures and lands where our research and teaching is taking place and which have been erased or ignored by colonialism. Further, we strive to address issues Indigenous communities are confronted with and to exploit physics and science for empowerment and self-governance. So far, we have started a collaboration with the Kahnawá:ke Environmental Protection Office and are currently planning a citizen science project (led by Dr. Gregor Kos, Concordia University) for air quality measurement in Kahnawá:ke, one of the eight communities that make up the Mohawk (Kanien:keha'ka) Nation, in the neighborhood of Tiohtiá:ke/Montreal. The small portable measurement devices employ laser scattering controlled by Raspberry Pi minicomputers. The distribution of these devices, the training of citizens and the collection of data will be maintained by community members.

In another subproject, students from racialized groups get the opportunity to apply for a research project which addresses science and colonialism. For example, one student is currently working on unfolding the different layers of colonialism in Haitian STEM education. In yet another subproject, students are developing a mobile *Decolonizing Light App*, an interactive educational tool for smartphones which augments physical knowledge of light phenomena with Indigenous perspectives, all of which are embedded in their political and historical contexts. Finally, we offer well-funded positions for graduate students to conduct current physics research, which are explicitly advertised in Indigenous networks.

With the variety of activities outlined above we hope to contribute to a science for all and to improve the accessibility and inclusivity of physics.

7. See the contribution by Zanon et al. in the present issue covering one of our activities regarding textbook analysis.

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OPEN SPACE: ENGAGING TEENS IN WESTERN NEWFOUNDLAND IN PHYSICS AND ASTRONOMY

BY SVETLANA BARKANOVA, STEVEN DAY, VICTOR HAYDEN, MARIA KILFOIL, ANGELINA PAYNE, JASMINE PENNEY, RENATE POHL, ALEXANDRA PORTER, AND KAYLA WARREN

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Jasmine Penney, a physics major and a contributing author, asked several team members about their experience with the program; below are the reflections by physicists Dr. Svetlana Barkanova (SB), Dr. Maria Kilfoil (MK), Steve Day (SD) and Victor Hayden (VH); Theatre Professor Renate Pohl (RP); Parks Canada Public Outreach Education Officer Angelina Payne (AP) and students Kayla Warren (KW) and Alexandra Porter (APR).

JP: What has been your favourite event so far?

SB: My favorite moment was the Grade 9 students' shriek of excitement as our 6-metre observatory dome started to move. Since we can no longer welcome youth on our campus due to the COVID-19 pandemic, we are trying to engage them with themed webinars, which, as it turned out, can be even more inclusive since we are no longer limited by distance. For example, this summer we had a talk by Dr. Niamh Shaw, an Irish Scientist/Engineer and award-winning STEM Communicator, as well as many other amazing women and Indigenous role models.

RP: I am particularly fond of one of our first events which provided younger children with the opportunity to dress in costumes and improvise to the story of *Muin and the Seven Bird Hunters,* a Mi'kmaw story tracing seasonal changes in the night sky. It fostered incredibly charming and spontaneous sensory-rich moments, which no doubt helped to solidify the night sky stories and lessons in the memories of both the young performers and the audience, and combined storytelling, trivia and tour of the observatory into one night.

SUMMARY

In partnership with NSERC PromoScience, Qalipu First Nation, Parks Canada, NL Hydro, and Memorial University of Newfoundland (Grenfell Campus), we are developing an integrative approach to STEM outreach by combining science and culture. Our team welcomes underrepresented youth on campus, visits rural schools, and hosts webinars with a diverse group of speakers, engaging more then a thousand participants per year. The main goal is to promote physics to Indigenous students, girls, and rural youth in Newfoundland. Each of the group members brings a different expertise that adds to the vibrancy of the team.

KW: My favourite event so far was in summer 2019 for the grade 11 and 12 students from a Girl Guides jamboree. It sparked a lot of questions about space and Indigenous culture.

AP: I really enjoyed the webinar we hosted this summer about careers for STEM in the future with all-female presenters.

MK: Our first joint event with our Qalipu First Nation partners on sky stories was the most memorable for me, establishing the essential DNA of our program and using our collective strengths and passion for promoting science through engaging with the community. I also think it is important that we are sending the message to students that doing research around outreach is a valuable and valid form of research.

APR: My favourite event so far was the event in celebration of International Women's Day, with TED-style talks highlighting the lives and successes of women from all different backgrounds. These strong and powerful women helped to give me the boost of confidence I needed as I pursue the very male-dominated degree of engineering.

SD: I enjoy any Grenfell Observatory tour when the weather allows visitors to observe celestial objects. The breath-taking expressions when visitors see the moon, planets or nebulae through a large telescope is very satisfying and a rare opportunity for the demographic.

JP: What has been the impact of your program so far, in your opinion?

APR: All the events we have had so far have been inclusive to all but with focus on different groups. I believe we have gotten our foot in the door with promoting physics to girls and Indigenous students, but I think the next step should be to better reach rural youth by working to overcome the barrier of travel [costs and time].

SB: Our joint events with community partners featuring Indigenous sky stories were especially popular, and I feel we are doing quite well featuring female role models. Reaching rural youth (truly remote, in our case) is more of a challenge, but we are working on that by investigating online delivery modes. Since we cannot travel anyway due to the COVID-19 pandemic, we are running a webinar series, which is even better for reaching all youth.

MK: With the help of our community partners, we have been expanding the network in schools that we need to reach rural youth. We have already seen an increase in youth in remote communities inquiring about programs in science, and we have had students connect with administrators of programs in Canada that they did not even know existed previously, such as Science North.

RP: Our events in the park, ongoing school tours and mini-lectures, focused Indigenous cultural events (*A Stellar Night with Muin* and *Sky Stories*), and *Spooky Space* (a Hallowe'en event) have all felt successful in terms of attendance, level of engagement, and general enjoyment. Some of the engagement has been second-hand, with parents attending public events. Time will tell whether these students eventually choose STEM careers, but I do believe that we have enhanced their experience of science through these in-person events.

VH: It takes time to begin to break down the misconceptions and societal norms. There is quite a lot of resistance to change, the so-called "It was good enough for…" effect. A lot of individuals hold beliefs that "because I am a …" they must fall into a certain category/lifestyle and that is that. Helping people understand that yes, they can do it if they try has always been important to me.

KW: We could have an even better impact with better promotion. I help to manage the Facebook and Instagram pages for our team and share pictures and articles promoting women and Indigenous people in science.

JP: What do you think was the main impact of community partnerships?

VH: Partnerships open new avenues to expand beyond the school environment and allow for the interaction of ourselves and students in a different atmosphere. We lose some of the constraints on our programs through partnerships, whether that be time or material coverage. Connecting with community groups allows us to expand and target specific groups who may be too nervous or intimidated in other situations. If we can relate our promotion of science to the subject that binds the community group together then it becomes far easier to encourage members of that group to at least think about a career in the sciences.

KW: Community partners have aided our success by giving us access to educational and material resources. The Qalipu First Nation partnership helped to gain insight into Mi'kmaq culture and diversify our presentations by incorporating traditional sky stories. The Makerspace allowed for the creation of materials to aid our presentations such as a fabric programable Orion to show constellations and circuits. And with Parks Canada, I was able to teach children about nocturnal ecology during a camping event.

AP: I think it broadens the perspective and the reach. We would not be able to engage so many Indigenous students without connecting with them through Qalipu First Nation.

MK: One of the things that really interests me is what sort of future are we creating for the next generation. I think we often don't think as farsighted as we might about the future of our country. The community partnerships have made our events stronger because the Qalipu and Parks Canada partners do think farsighted, at their core. These partnerships have brought together all the different resources and networks we all can draw on.

APR: Community partnerships have helped illustrate that science is applicable almost everywhere, not just in your science class. Bringing different organizations together allows for the combination of a vast variety of themes. Joining forces in the community has helped to amplify the idea that science is a broad and extensive subject to those youth that may not realize it yet.

RP: Our partnership with Qalipu First Nation has been invaluable in contributing Indigenous voices, stories, and culture to aid in connecting with Indigenous students. Parks Canada got students out of the classroom and viewing the dark sky, while a local youth theatre group provided a creative mechanism to connect Indigenous culture with astronomy. Team and student volunteers at Grenfell campus led observatory tours and activities combining art and the physics of the EM spectrum and colour. These partnerships have helped to add creativity and a wider cultural perspective, both of which aid science promotion through positive emotional experiences attached to the learning/memory experience.

JP: What have you learned from your experience with this project?

AP: In my experience, I have learned the importance of community partnerships to promote awareness and inspire participation through as many channels as possible. I also really value the connection between traditional Indigenous ways of knowing and modern science.

MK: Our community partners have been a source of learning and inspiration to me. As well, the degree of positive response from female role model presenters to whom we have reached out to share science and career advice in the webinar series this summer has been gratifying and inspiring. I have learned that there is a whole deep resource of people wanting to be involved.

RP: I've learned the importance of good survey data collection as a metric of success (something not typically used in my field), as well as the need to set up clear and efficient communication methods when working within an interdisciplinary team. Working with partnerships means working with many different schedules and ways of communicating — I've learned how to stay flexible to allow for these differences, while respectfully keeping the program moving forward.

SB: Excellence in science outreach, just like in science, depends on diversity of ideas and people. Ask for input from your community! I have been doing physics outreach and working on issues faced women in science for years, but nowhere close to the scale we have now, allowed by an NSERC PromoScience grant. I am constantly learning.

APR: I was uninformed of how physics encapsulates more than the topics discussed in a first-year physics course: I have learned that introductory physics courses do not represent the discipline and there is so much more to know.

AP: Digital education is a very good medium if there is enough promotion.

In closing, we would like to express our deep gratitude to the NSERC PromoScience program for enabling us to expand our efforts to attract underrepresented youth to careers related to science and technology. We feature female and Indigenous role models, engage Indigenous storytelling, strive to provide wider access through webinars, discuss a vast range of career opportunities, and emphasize a diverse set of skills required in modern science, such as cooperation and communication. A science education based in physics provides students with a valuable and flexible skill set that opens doors to a wide variety of productive and enriching careers; this in turn leads to a successful local knowledge-based economy and increases rural resilience. The program is scalable and portable to any location with the dark sky, university campus, and engaged local partners. We are especially looking forward to extending virtual visits to remote schools enabled by recent improvements in rural internet connectivity.

The Racist Experiences of a Black Post-Secondary Student in Canada

by Vimbikayi Rachel Chimuka

Before the resurgence of the #BlackLivesMatter movement in June, following George Floyd's undeserved death, I would have claimed that there is no anti-black racism in Canada. I wouldn't have said that because I didn't experience it, but because I, like many other Black women, had become so skilled at gaslighting myself that I convinced myself it didn't exist.

The #blacklivesmatter movement "woke" me up.

I came to Canada in 2014 from Harare, Zimbabwe and completed my BSc. with a First Class with Distinction. Now that I'm currently halfway through my MSc. program, I say I was one of the lucky ones; mentally strong enough to rise above the racism I've experienced, but weak enough to gaslight myself, and take the blame for failures when systemic racism was responsible.

Much of the covert anti-black racism I've experienced has been from my peers. In my third year of university, I was assigned a group project in a class with all white peers. I didn't know that this was going to be the worst group project of my undergraduate career. My ideas were completely ignored. My groupmates acted as if they didn't hear me speak, then later repeated some of my suggestions and accepted them as their own. In the few instances when they did listen, I was told my ideas were "too complicated" or "too detailed". Eventually, I felt defeated and contacted the professor for help.

Professors are key players in the class setting; their actions have an immense, long-lasting impact on all students. Unfortunately, I've often found myself in several classes with covertly racist professors. To some professors, all Black students looked similar. It didn't matter if there were two or ten of us in the class, or if the other Black people were men! How was I supposed to stand out? To others, I was a walking African "Siri" whom they could access if they had questions about Africa or Blackness. My professors would spend more time asking about how the length of my hair dramatically changed overnight or how my famous Zimbabwean president stayed in power for over 35 years, than on my academic progress. While I agree that professors should get to know their students, talking about my culture and background shouldn't be the main topic of conversation when I come to office hours for academic help.

Summary

This testimonial will detail my racist experiences as a black post-secondary student in the sciences in Canada. I will discuss the everyday racism I experience from peers and professors in my courses, as well as the covert racism that hampers my ability to communicate my research during scientific conferences.

The worst racist experience of my undergraduate career occurred outside the classroom. We went on a class field trip in 2016. As usual, I was the only Black person in the class. At the end of a long day hiking and collecting data, our class went for dinner at a local restaurant. The waitress came over and asked all 15 people at the table what they wanted to order except for me. I thought she would come back for me, but she never did. I tried to get her attention several times, but she simply ignored me. She only came over when my white classmates waved at her. Once she arrived, she asked them what I wanted, as if I wasn't there. My classmates had to put the order in for me because she wouldn't interact with me. I was so afraid that in her disdain for me, she may have contaminated my food, but after a long day I had to eat something.

My racist experiences outside the classroom also include encounters at research conferences. I signed up for a particular poster competition at an annual conference where, unsurprisingly, I was the only Black participant. I stood by my poster for 10 minutes before anyone came over. The first visitor — a middle-aged white man — approached me and asked me where I was from and how I got to Canada. He proceeded to leave without asking me anything about my poster. A few minutes later, another white man came and asked me what my poster was about. Before I could finish my sentence, he told me to "hurry up" and that he "didn't have all day". The same man went on to spend the rest of his 30-minute break at the other white girls' posters.

Professors focusing on our identity, rather than our education, limits our learning and feeds into the many difficulties Black scientists have to overcome. Dealing with these encounters at conferences, rather than answering questions and receiving scientific feedback, make it difficult to network and attain the standard of excellence we know we are capable of.

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Black Women in Canadian Physics

by Thelma Akyea

As a Black Canadian woman, graduate student, teacher and mother who attained a bachelor's degree in biophysics, my experiences highlight challenges that drew me toward or away from physics. In this piece, I consider some research on equity, diversity, and inclusion (EDI) issues in physics and I pose critical questions that drive my teaching practice and research. I hope my experiences will prompt stakeholders to further address EDI issues in Canadian physics programs, with a specific focus on Black women.

PRE-UNIVERSITY SCHOOLING

In grade 8, I wanted to learn about a Black woman scientist for my independent study project. The class library contained biographies about different Nobel Prize-winning scientist — no Black women. The only non-white men were George Washington Carver and Marie Curie. I settled upon Dr. Carver's biography. In a time before Google and a variety of diverse resources in science, I settled with the options I had. A good friend, Karon, also stymied by the limited choices available, studied the javelin. On presentation day, after I spoke of Carver's innovation and activism while Karon wowed us with the physics of the javelin. I was stimulated by her passion for physics. Thanks to her project, I learned the satisfaction of physics study.

During my final year of high school physics, I could not settle on a topic for independent study. When I asked Mr. Charles, my outstanding teacher, how to combine my interest in the human body with physics. He responded, "Have you heard of biophysics?" I had not. He explained how biophysicists apply physical principles to understand biological systems. I designed an independent study, and modeled stress and strain on the human femur during rest and locomotion. I researched twisting, torsion, and compression. With chicken bones, my experiment would model the stress and strain in a human femur.

The weekend before the experiment, I pulled the bones out of raw chicken and left the bones in a container on a kitchen counter. As I got ready for school two days later, I opened the container and met the sickening smell of rotting poultry. I hurriedly washed the bones in bleach, dried them and rushed out the door. In the physics lab, Mr. Charles asked, "Why are these bones so dry and brittle?" I shrugged and explained the bleach. Mr. Charles laughed and said, "Well, here goes!" When tested, most bones snapped like kindling, but I was ecstatic when one bone withstood 3° of torsion. This experience, coupled with a great final exam score, solidified my passion for physics and set me on the path to study biophysics in university.

SEEKING A PLACE IN PHYSICS

If I had seen myself in the curriculum, it would have supported my sense of belonging in Canadian science at a young age. Instead, my class library demonstrated Black women's erasure in Canadian science. Research shows that recognition is one of the hardest characteristics for minority scientists to attain [1]. In Canada, inroads toward confronting Black women's invisibility can start in the elementary classroom, by promoting Black women's research in Canada and sharing their stories.

In contrast, my partnership with Mr. Charles exemplifies how a strong affinity for physics develops. When students and educators develop good subject knowledge and a keen interest in physics, the results are long-lasting [2]. I felt like a biophysicist during that investigation. I imagined myself conducting similar research in the future. To work alongside a physics teacher who seemed to be as interested in the project outcome as me was life-altering and set me on the path to pursue a biophysics major in university. While the experiment was unsuccessful, the partnership was a victory.

LEARNING IN UNIVERSITY

In university, I was part of a small cohort of biophysics students. We developed a close friendship during our time together. We often collaborated on physics problems to complete assignments and prepare for tests. This collaboration helped me to think critically about solving

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Summary

Thelma Akyea is a mother, aunt, wife, sister, and daughter. She is an elementary teacher, working in Toronto. Thelma is also a doctoral candidate at OISE, University of Toronto. Her research interests include gathering the educational experiences of Black women in post-secondary physics and astronomy.

problems. Even though the program was competitive, our camaraderie boosted my confidence.

In my second-year physics course, I was the only Black person in an all-white physics class. I was often the only person in the front row, which was an opportunity to ask questions and volunteer answers. Once, the professor requested a volunteer to determine a missing variable within one Schrödinger equation. I volunteered and solved the question correctly in front of the class. I was proud of myself. The surprised look on the professor's face, however, quickly replaced any satisfaction I felt. His expression suggested he did not expect me to know an answer that no one else knew. While normally he would ask students to explain their thinking, at that moment he moved on without asking me to elaborate. His disbelief in my capabilities, in addition to other experiences of exclusion in the second-year physics course (difficulty finding a lab partner, no one accepting me into their study group, and so on), left me feeling alienated.

BEING SEEN IN PHYSICS

I attended a predominantly white Canadian university, and in many courses, I was the only Black person, so I stood out. Yet, I was *not seen* as a credible physics student by professors and peers who were a part of the second-year physics courses. My university experience aligns with many Black women's stories from across Canada in varying departments [3,4]. However, the friendships I cultivated within the biophysics department made the undergraduate journey bearable. Black women use many coping strategies to stay in physics [5,6]. Biophysics community support helped me cope with many obstacles in undergraduate study. Our socials, late-night study sessions, and ongoing banter were essential because, through our interaction, I knew they saw me for who I was.

CRITICAL QUESTIONS

- How might you find out more about Black women's contributions to research in Canada?
- Where could you insert Black women's research, storied histories, and obstacles faced into my curriculum/prospectus/deliverables?
- How do teachers, professors, and department chairs in physics develop relationships with Black women that provide a setting to address issues that stem from intersections of racism, sexism, and classism in physics?

CLOSING THOUGHTS

It is well-known that Black women and Black girls address obstacles on multiple fronts that inform their identities in physics [7-9]. What do we know about intersections of race, class, and gender for Black women in Canadian physics? Since the narrative of Black women in Canadian physics is less discussed, now is the opportunity for Canadian physics organizations to learn more. Department heads, physics educators, administrators, and organizations should (*a*) collect qualitative data on the experiences of Black women in physics and (*b*) address the inequitable representation of Black women in physics across Canada. Furthermore, I implore *Physics in Canada*'s readership to implement changes in their spheres of influence that dismantle the barriers that Black women face in Canadian physics.

GRATITUDE

I offer my sincerest gratitude to the family, friends, and colleagues who continue to support my research (Wole, Vivienne, De Gyal Dem and Prissy) and who take me for photoshoots (Micah and Brad). Peace.

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DIARY OF A 21 YEAR OLD NIGERIAN PHYSICS GRADUATE IN CANADA'S SMALLEST PROVINCE

BY OYEINEMOMOEMI STEPHANIE OMONIBO

January 5th, 2015. I arrived at Charlottetown, PEI at the age of 16 to pursue my career goal of becoming a computer scientist. This was after I had been told in high school to pursue something a bit more "realistic" than Astronomy. Job security had always been a top concern for African parents, not "passion". The only options parents loved hearing were doctor, lawyer, engineer.

December 15th 2019. I graduate with a degree in Physics and minor in Math. These pure science careers that would make any African parent cringe. I do not blame them.

STRUGGLES AS A PHYSICS MAJOR MINORITY

I am not only not a white male, I am female and to take it a step further in the underrepresented chain, a black female.

Representation matters more than you think. Being able to see someone who looks just like you, doing something that you would love to do, makes all the difference in the world.

I had only encountered one other black person, in all of my time in Canada and actually all twenty one years of my life, pursuing a physics degree. This was during year four of my undergraduate degree when I attended my second AUPAC (Atlantic Undergraduate Physics And Astronomy Conference). The first time I had attended that conference was the year before. I was the only black attendee. I was excited but also uncomfortable, felt out of place and simply did my best to get through the weekend. Imagine my excitement, when I finally saw someone that looked like me, and most importantly: it was a woman! It felt less lonely.

I recall when I landed my first physics job as a research assistant. It was a dream come true. I had been asked by three individuals what I was doing for the summer; my response was met with a lack of excitement, which was further met with confusion. "What is that?", "Is that your real job?", "I mean, what is your actual job?".

"Oh wow, good luck with that" is the most common response I received disclosing my major. I think "alien studies" would get better responses.

I had a lot more struggles that if I were to share, this would end up being a book.

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HOW TO ACHIEVE A MORE RACIALLY AND GENDER DIVERSE ENVIRONMENT

As you read these, I ask that you do so with a very open mind. My main goal is not to criticize but simply to highlight blind spots and genuinely inspire change.

- Stop being so cliquey. If the world were a high school and subjects were people, Physics would be the mean girls that are hard to be friends with. One would have to look a certain way (white) and have a certain status (male) to be included.
- Financial Aid — it's quite straightforward, if you want more diverse students and professionals, create financial help
- Hire professors that are not just white males. Have diverse board members. Difference in opinions and backgrounds lead to breakthroughs, not conflicts.
- A society of black physicists in Canada would not hurt.
- Do not forsake the years of your youth. People I have conversed with pursued a physics degree because we had a really good physics teacher who was passionate about the subject. If you want more people in the field, show them why you are in it.
- Don't argue, Listen! Don't be defensive, be empathetic. It is out of love that change occurs.
- Promote and value careers and physics opportunities besides research. If one does not want to be a researcher or a teacher, they should still be able to pursue a Physics degree because it presents lots of career paths. If these options are highlighted, it will attract people with different backgrounds.

A lot of support towards underrepresented minorities (race, gender, etc.) has always been word of mouth: platforms to speak up, diversity events, the list goes on. Creating diversity, equity and inclusion is not doing someone a favour, it's giving someone what is rightly theirs. It is not something to pat yourself on the back for. Changes start small, and drops of water make an ocean, but consistency is key.

Physicists are some of the most patient, competitive, stubborn, persistent people that I know. Those skills have led to amazing breakthroughs in the world of science. If only we applied a little of that tenacity towards improving equity, diversity and inclusion in the Physics community, we could change our community as well.

MULTIRACIAL EQUITY IN CANADIAN ACADEMIA

BY SHANTANU BASU

The summer of 2020 has been a time of reckoning and reflection on racial issues in North America. Well publicized cases of mistreatment of Black and Indigenous people by police, in the United States and Canada, led to a movement highlighting these injustices, punctuated by street protests that people of all races have joined. The isolation imposed by the Covid-19 pandemic may also have contributed to this movement, by giving people the time to reflect on larger societal issues and act on them.

How are Canadian universities faring? In a country that proudly promotes its multiculturalism, Canadian universities may see themselves as a bastion of diversity and inclusiveness. Does the data support this? Well, here is the first problem: *we don't keep much data*! In 2017, the Canadian Broadcasting Corporation [1], as part of an investigation on diversity, asked 76 Canadian universities if they kept data of the racial backgrounds of their students; 63 of these universities said that they did not. Tracking the race of university faculty and staff is also generally lacking. Some people think that collecting such data is not allowed, but according to the Ontario Human Rights Code, collecting such data for a Code-consistent purpose *is* permitted, and is in accordance with Canada's human rights legislative framework [2]. In the United States, the federal Affirmative Action program has meant that organizations receiving federal funds have to document their equity practices and metrics, and it has unquestionably led to significant changes in the racial diversity of American university campuses [3]. In Canada, we have no such mandate, so racial equity in universities has been left in the hands of those who run the universities. There is much to be done. As scientists we recognize the importance of quantitative data and would rightly feel that avoidance of data is unacceptable. Without data on diversity, there is simply no accountability. While I could relate heartbreaking stories of inequity that I personally know about, without data on diversity in the university cohort, in hiring and promotion practices, on salaries, etc., such stories remain anecdotal and action is easily avoided.

SUMMARY

Shantanu Basu is a Professor of Physics and Astronomy at Western University. He is an astrophysicist who studies the formation of stars and planets. He served as Chair of Western's Department of Physics and Astronomy and is a member of its faculty union UWOFA's equity committee.

Nevertheless, here is some data that we do have about Black, Indigenous, and People of Colour (BIPOC) representation in academia. Black people constitute 6% of university students in Canada but only 1.9% of faculty members [4]. Indigenous people are 5% of the population but less than 1.5% of faculty members [4]. Blacks and People of Colour (hereafter BPOC) constitute at least 22% (2016 census) of the population and 40% of university students [4]. Their share of university faculty and staff positions are well below these percentages. A survey of physics departments in Canada estimated that there were less than five Black faculty members in the entire country and no Black women [5]. POC have greater representation, but still below their reference population numbers and spread unevenly.

The Canada Research Chairs program has taken the transformative step of requiring universities to meet equity targets for CRC holders. By 2030, the representation of women, BPOC, Indigenous people, and People with Disabilities should be 51%, 22%, 5%, and 8%, respectively, with a smaller percentage target of each that was to be implemented by the start of 2020. These targets were established after a legal settlement was reached from a complaint brought by eight academics to the Canadian Human Rights Commission [6]. The CRC goals are still modest, given the decade long implementation period, and the target representation of the fast-growing BPOC population for 2030 is based on the 2016 census [7]. There is also a concern that BPOC women (hereafter WOC) will be left behind in this implementation. As a result of this requirement, universities are keeping metrics of its CRC holders and I hope this will extend to the total (full-time and part-time) faculty and staff cohorts.

I focus now on my institution, Western, not just because I know it best, but because some of our experiences may be common across Canada. Ethnic/race data at Western is limited by the participation rate of respondents to a voluntary equity survey, currently estimated to be about 70% in the case of faculty members. According to available data presented through Western's Equity and Human Rights Services [8], the percentage of BPOC staff and faculty are

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8.1% and 14.5%, respectively, while the percentage of Indigenous staff and faculty are 0.8% and 0.5%, respectively. The BPOC and Indigenous staff percentages represent one-half and one-third, respectively, of the reference populations in London. The BPOC faculty percentage is about two-thirds of the national level, and is also spread very unevenly, with one Faculty in the university carrying a significant part of the cohort. At the student level we don't have firm numbers, but they seem to be similar to the national numbers of 40% BPOC students at both the undergraduate and graduate levels [4]. Our student-body is offering us an obvious pathway to creating the diverse faculty cohort of the future.

An incident of egregious racism against a WOC student at Western in 2019 led our President to constitute an Anti-Racism Working Group (ARWG) that was tasked with gathering reflections from all university community members and issuing a final report. The ARWG report at Western [9] reveals a pervasive culture of racism that remains deeply entrenched and privileges some groups over others. It is unlikely that this is unique to Western. Findings included that racism is gendered and intersectional, in that WOC are the most likely to experience it. Students reported a desire to see more professors and support staff (including notably in the residence hall experience) who look like them. Training of all personnel on cultural competency and the nature of racial microaggressions was recommended. Finally, it was recognized that the scale of marginalization could not be fully understood or acted upon until there was robust and publicly accessible demographic data on Western's student, faculty, and staff populations.

In the United States, the American Institute of Physics undertook a two-year study by a multidisciplinary panel called TEAM-UP to assess the participation of African-American students in physics. The TEAM-UP report [10], released in November 2019, draws several conclusions. I note the first two: 1. Fostering a sense of belonging is essential for student persistence and success; 2. To persist, students must perceive themselves, and be perceived by others, as future physicists and astronomers. These are powerful insights and a call to action, illustrating that such a climate is largely lacking. Ask yourself: is it possible that in your department BIPOC graduate students do not have the access to faculty members for support and mentorship that their White colleagues take for granted?

One of the most effective ways to create a successful environment is to achieve a minimum level of gender and ethnic diversity. According to a study by the consulting firm McKinsey [11], companies that successfully implement Equity, Diversity, and Inclusion (EDI) are likely to outperform those that do not. They found that for EDI success employees need to feel and perceive equality and fairness of opportunity in their workplace. There is also a clear correlation between superior performance and having at least 30% female representation on executive teams; the correlation with ethnic diversity was at least as strong. In this article I will adopt 30% representation as the minimum requirement for creating an inclusive environment that is less likely to be described as "chilly". Another important study is the 2019 Universities Canada report on EDI [4]. It shows that gender balance has been achieved in most university senior leadership positions, but still lags somewhat at the top positions of President, Provost, and VP Research (although the percentage of women is now between 33% and 39% in these categories). However, the BPOC representation in senior leadership is only 8.3% and Indigenous representation is 2.9%. More than 70% of universities say that they either have no EDI strategy or action plan, or that it is still in development. Only 13.4% of universities say that they have an EDI plan in place and are fully implementing the plan and reporting on progress.

Here then are three main problems that I believe we face in Canadian academia when it comes to EDI:

1. A lack of comprehensive data on demographics, and on equity in internal processes like hiring, promotion, career advancement, and salaries, thereby reducing accountability for practices that are harmful to EDI.
2. The available data already points to systematic under-representation of BIPOC among faculty and staff, and in senior leadership positions.
3. Surveys of the climate/culture are turning up notable problems faced by BIPOC students, faculty, and staff.

The above issues are notable and are increasingly challenging to remedy as one goes down the list. Here are three recommendations that I feel are the minimum requirement to move the needle.

1. **Gather data**. All universities (and faculty associations or unions) should gather demographic data on their cohorts. While ethnic identity may be fluid and some may choose not to pick a category, it is important to emphasize that this is being done to improve EDI awareness and performance. I believe that most people will respond positively, and we can strive to collect data with at least as much completeness as do our American counterparts [12]. Furthermore, a systematic review should be done on hiring practices, the promotion and tenure process, career advancement, and salary as it relates to race and ethnicity. Most organizations have already done this when it comes to gender and are familiar with the methodology.
2. **Action toward creating a diverse and inclusive environment**. We need to acknowledge that search committees are plagued by implicit bias and affinity bias. Their decisions mean that universities can be very slow to diversify due to the length of tenured positions. Diversity training alone has proven to not make a difference [13,14]. All universities need to mandate gender and BIPOC diversity on their search committees, with at least 30% representation of women and

at least 30% representation of BIPOC members (of course some members will fall into both categories). A target should be set within each unit to reach at least 30% BIPOC faculty members within a reasonable time frame (less than 10 years!). Having a diverse cohort is ultimately the key requirement in building an inclusive environment that will make the institution attractive to BIPOC faculty and students. Faculty candidates should be required to submit diversity statements and expect to be asked about what they will do to enhance diversity. Departments should have mission statements about their commitment to diversity and a safe environment free of discrimination, bullying, and harassment, with concrete action plans to follow through.

3. **Support for BIPOC students, the faculty members of the future**. We have an amazing opportunity before us, given that at least 40% of the national undergraduate and graduate cohorts are BIPOC. A deeper effort can be made to recruit Black students, and Indigenous student numbers are still well below the population average. These can indeed be done, as the rapid success of the University of Toronto's Community of Support initiative for its medical school demonstrates [15]. BIPOC students often feel lost without mentors or role models with whom they can identify. If a student finds a teacher or mentor who looks like them it can have a great impact [10]. We can foster networks at each university and at the national level, so that BIPOC students don't just seek support within their own department, where it may be limited or not exist. Excellent ideas like the Women in Physics conferences can be used as a template for building events (now online, which can expand inclusivity) to present work and connect with colleagues. Fostering a sense of belonging brings the confidence among BIPOC students that they can be the professors of the future.

We are currently in public health crisis that has also spawned economic and social crises. Higher education is strongly affected, and many of us are undoubtedly wondering if things will ever be the same. Let us also find an opportunity to remake academia in a more equitable mold, ushering in new ideas and progress in physics at the same time.

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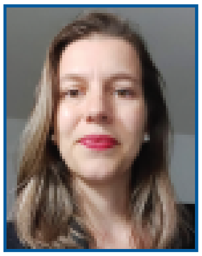
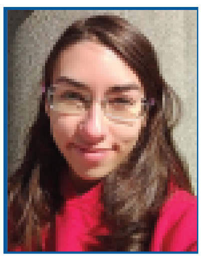
Who Gets The Picture? Diversity In Canadian Science and Physics Textbooks

by Tatiana Zanon, Melissa Mendes, Anick Jasmin, Gita Ghiasi, and Tanja Tajmel





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Textbook content is considered to have a significant impact on the knowledge construction and transmission process, providing and constructing a specific ‘reality’ of society [1]. Science textbooks highlight the historical work of influential scholars who have shaped the field, hence embodying students’ imaginations of who scientists are, have been and can be. Thus, the lack of representation within these materials can potentially negatively impact their identification with science [2]. Likewise, images in science textbooks communicate critical information about the society and its values [3].

Studies have shown that school textbooks, in general, are filled with stereotypes and implicit messages of female inferiority [4,5]. If present at all, Indigenous people are likely to be depicted inferior to Europeans [6], and Black people are depicted in the context of a subordinate position, *e.g.*, performing manual labour [7]. Diverse role models are paramount for underrepresented groups since they usually do not have access to mentors that share “salient elements of their identity” [2].

There exists no study so far that reveals how Canadian science and physics textbooks are representing women and minorities. With our study, we aim to close this gap.

Summary

In this study, we investigate the representation of women, Black and non-Black People of Color (NBPoC) in Canadian science and physics textbooks. First outcomes reveal a huge gender gap in undergraduate physics textbooks (twice as many men as women) and a particular underrepresentation of Black people in scientific contexts. No images of famous or historically known Black or non-Black PoC scientists could be identified, all famous and highlighted scientists across the textbooks are white.

PHYSICS AND SCIENCE TEXTBOOKS: STATUS QUO REPRODUCERS?

In our ongoing research, we are investigating the representation of women, visible minorities, Indigenous peoples and persons with disabilities in Canadian elementary and secondary school science textbooks and undergraduate physics textbooks used at Canadian universities and colleges, compared to their representation in Canadian society. Here, we present preliminary results of our ongoing study regarding the representation of women and visible minorities.

Our research questions are:

- Do Canadian science (elementary/secondary school) and physics (colleges/university) textbooks represent the demography of the people living in Canada?
- How are members of different groups portrayed?
- Who is portrayed as a scientist?

For the image analysis, we applied a deductive coding method and developed a coding scheme consisting of categories, definitions, examples and coding rules as an instrument, The categories defined were *gender*[1] (feminine/woman (F), masculine/man (M)), *race/racialization* (White (W), Black (B), Non-Black People of Color (NBPoC)[2]), *role/activity* (scientific activity (Sc), famous or historically known scientist (HSc), athlete/sports (Ath))[3], *visible disability*, and *age*[4]. Each category considered the subcategory ‘not identifiable’ (NI). The calculation of

1. We considered a nonbinary gender category in the pilot study but the interrater reliability for this category was too low to include this option in the coding scheme for the main sample.
2. Our pilot study revealed that it was not possible to reliably identify Indigenous peoples on basis of any visible characteristics. Therefore, Indigenous people have not been considered as category in the image analysis. However, in our ongoing study, we are also analyzing text through a decolonial lens, and how Indigenous peoples are constructed as ‘Others’.
3. We considered athletes/sports (Ath) as category because sports is commonly used in physics textbooks to illustrate concepts of physics (particularly in Mechanics). Additionally, previous research showed that Black people tend to be represented as athletes [14].
4. We also included ‘visible disability’ and ‘age’ in our analysis. Here we are only presenting preliminary results for the categories ‘gender’, ‘race’ and ‘role/activity’.

TABLE 1

Canadian demography retrieved from Canadian census 2016 [13] compared to data obtained from our analysis. The lower part of the table shows the textbooks' representation of women (F), men (M), Black and Non-Black Persons of Color (NBPoC) as famous/highlighted scientists (HSc) or involved in science activities (Sc).

	DEMOGRAPHYCANADA (%)	SCTEX (%)	PTEX (%)
F (overall)	50.75	43.30	30.41
M (overall)	49.25	49.04	61.21
Black (overall)	3.48	10.00	14.82
NBPoC (overall)	18.80	16.60	15.58
F/ Sc		24.76	0.76
F/ HSc		3.33	0.38
M/ Sc		22.38	1.14
M/ HSc		6.67	3.04
Black/ Sc		4.29	0.00
Black/ HSc		0.00	0.00
NBPoC/ Sc		11.11	0.00
NBPoC/ HSc		0.00	0.00

Cohen's kappa coefficients[5], a statistical quantity that measures the agreement between two independent raters and controls random agreement [8], yielded a minimum of 0.81 for each category. The inter-rater reliability can thus be considered as almost perfect.

The data presented here results from our analysis of two science textbooks (SCTex; grade 8 [9] and grade 9 [10]) and two physics textbooks [11,12] (PTex; undergraduate level). For the analysis, we selected the most widely used textbooks across Canada[6]. For SCTex, all images (210 depicted individuals)[7] were analyzed; for PTex, we selected one topic, Mechanics, and analyzed all images (263 depicted individuals). In total, 473 depicted individuals were coded.

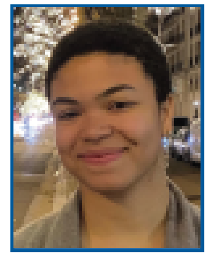
FIRST OUTCOMES

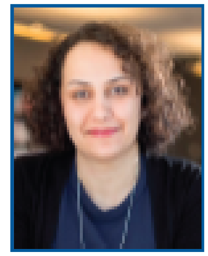
Table 1 gives an overview of our gained data compared to Canadian demographic data. In both textbook categories, feminine individuals (50.9% of the Canadian population) are underrepresented. The gender gap between masculine and feminine representation is 5.7% for SCTex and 30.8% for PTex. Individuals coded as Black are in both textbook categories overrepresented (SCTex 10.0%, PTex 14.8%) compared to their representation in society (3.5%). NBPoC (visible minorities without the category Black) are slightly underrepresented (18.9% in Canada versus 16.6% in SCTex and 15.6% in PTex).

The ratio of White, NBPoC and Black is different when considering the role/activity of the depicted person. In SCTex, in the subcategory scientific activity/famous scientist, 4.3% of the individuals are Black and 11.1% NBPoC. In the same category in PTex, no Black and no NBPoC individual could be identified, whereas the representation of Black individuals in the category Athletes/Sports increased.

In SCTex (Fig. 1), there is a small difference between masculine and feminine persons depicted in science-related activities (22.38% masculine versus 24.76% feminine). However, regarding highlighted or famous scientists, men appear precisely twice compared to women (6.67% men versus 3.33% women). Regarding race, in science-related activities, NBPoC are depicted in 11.9%, Black in 4.28% and White in 30.96%, whereas only white persons are depicted as famous or highlighted scientists.

5. Values for Cohen's kappa coefficients range from 0 to 1, where 1 is closest to complete agreement.
6. Information was retrieved from the Ministry of Education of each Canadian province.
7. Images with more than one person were analyzed by coding each person individually.





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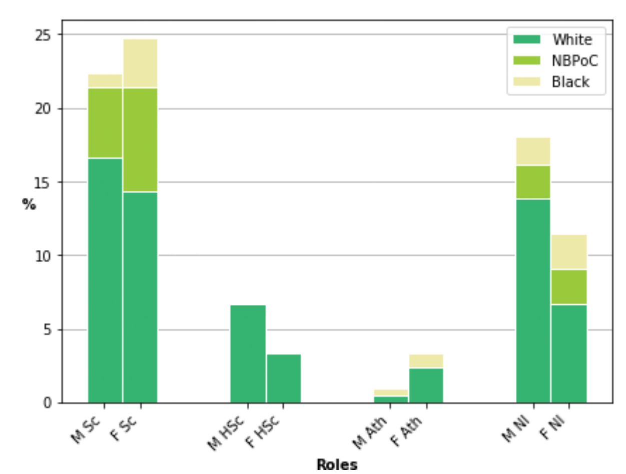

Fig. 1 Representation of gender (M, F), race (White, NBPoC, Black) and role (scientific activity (Sc), famous scientist (HSc), athlete (Ath), not identifiable (NI)) in SCTex.

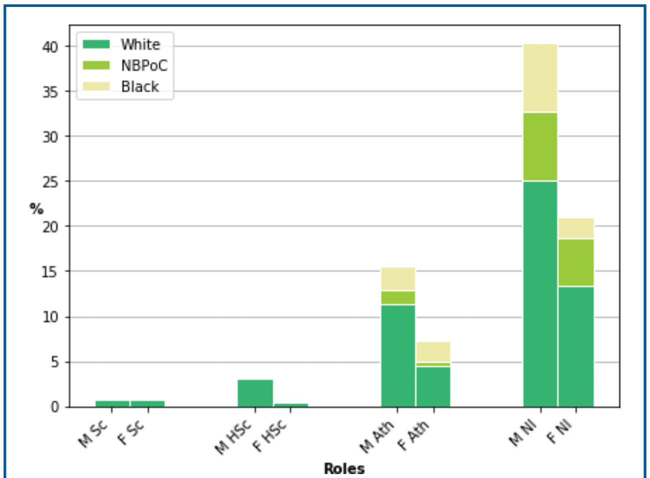

Fig. 2 Representation of gender (M, F), race (White, NBPoC, Black) and role (scientific activity (Sc), famous scientist (HSc), athlete (Ath), not identifyable (NI)) in PTex (topic Mechanics).

In PTex (Fig. 2), in the topic analyzed, there was a small difference between the representation of masculine and feminine individuals in science-related activities (1.14% masculine versus 0.76% feminine). 3.04% men versus 0.38% women are depicted as famous or historically known scientists. Black and NBPoC persons are depicted as athletes; however, no Black and NBPoC person could be identified in science-related activities nor as famous/highlighted scientists.

CONCLUSION

Our preliminary results, although limited, reveal that Canadian elementary/secondary school science textbooks (SCTex) and undergraduate physics textbooks (PTex) may represent women and minorities differently. The overrepresentation of visible minorities in SCTex indicates the intention to represent minorities and the diversity of society. However, in science (performing a scientific activity or being a famous/highlighted scientist), marginalization becomes conspicuous. At the undergraduate level, in PTex, visible minorities are marginalized even in non-scientific activities, particularly women. In undergraduate Physics textbooks, Black or non-Black persons of color are neither represented as scientists nor performing a scientific activity. Across all textbooks all famous scientists are white.

Our results demonstrate the necessity of an intersectional lens in studying marginalization and underrepresentation, including the individual's role in a specific field. Furthermore, the findings call for a critical approach regarding the representations of minorities to showcase 'diversity'. Overrepresenting racialized people or visible minorities in non-scientific contexts by simultaneously underrepresenting them as scientists does not contribute to an equitable representation, but rather reinforces and centers whiteness in the STEM fields.

ACKNOWLEDGEMENTS

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Equity, Diversity, and Inclusion: A Graduate Student Perspective

by Sarah Dawson, Carmen Lee, Wyatt Kirkby, Jacqueline Wightman and Rachel Pillsworth

In the past months we have witnessed a massive international push to address racism towards Black, Indigenous, and People of Colour (BIPOC). We have both the opportunity and responsibility to harness the momentum of this movement and translate it into a more equitable, diverse, and inclusive Physics community. It is within this context that we, as representatives of the graduate students in the Physics, Astronomy, and Radiation Sciences programs at McMaster University, are writing this article. Here we describe how we are organized, introduce the equity, diversity, and inclusion (EDI) initiatives we have put forward in our department, discuss proposed anti-racism actions in the context of the #ShutdownSTEM event of June 10, and identify the barriers we have encountered throughout this process. It is our hope that this article will serve both as reference material for other groups and as a testament to the unique role that graduate students are playing in improving EDI in academia.

The graduate students in our department are organized through a graduate student association named the McMaster Astronomy-Physics Student Association (MAPSA), and an EDI-focused student group named Promoting Inclusion in Physics and Astronomy (PIPA). We are also connected to the broader University community through the Science Graduate Student Association (SciGSA), the Graduate Student Association, and the union of academic workers at McMaster, CUPE 3906. These groups work to provide a supportive environment for students in the University.

Graduate students in our department are active in bringing science communication to the public — for example we run the Hamilton branches of Science on Tap and Pint of Science, which are outreach events that take science to the public in a local bar. We are also the primary presenters at the W.J. McCallion Planetarium, with presentations developed for children and adults. Notably there have been Planetarium presentations developed in collaboration with Six Nations and McMaster's Indigenous Studies Program. We also organize an annual outreach event called Girls in Science Day, which promotes science to girls attending high school in the city of Hamilton.

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Summary

We discuss the role that graduate students play in shaping EDI initiatives and the structural barriers that we must overcome to do that.

To address the issue of low enrollment of BIPOC students at the undergraduate level, we have proposed expanding the outreach we already do in order to include underrepresented communities. One proposal is to seek partnerships with nearby high schools that have large Indigenous populations, using spare lab equipment to run labs and sidewalk astronomy sessions. Graduate students would play a vital role in organizing and otherwise providing the labour for these outreach events. The position of full-time outreach coordinator has existed in previous years; however it has since been eliminated due to budget cuts. We are advocating that the Department and the Faculty of Science reintroduce the outreach coordinator positions, and support them with paid Teaching Assistants.

We organized the #ShutdownSTEM event in our department, which consisted of four EDI-specific events: a town hall discussion on department hiring practices, focused breakout sessions within research sub-fields, the CAP Special Session on EDI, and a department-wide conversation about community outreach. Following these discussions, MAPSA representatives and the PIPA executive wrote an open letter to the faculty and staff in the Physics Department in which we identified a series of action items for the department to directly address to promote inclusivity. Major items in the letter include a call for a BIPOC-specific faculty hire and the creation of targeted research scholarships for BIPOC students at the undergraduate and graduate level to encourage higher retention.

The faculty response to our advocacy has been positive in the months following #ShutdownSTEM. Owing to the consistent efforts of MAPSA and the general graduate student populace, steps are now being taken by both the Physics and Astronomy Department and the Faculty of Science. For example, EDI and micro-aggression training will now be openly available and promoted to all faculty, staff and Teaching Assistants. Following the discussion led by CAP during the Special Session on EDI, MAPSA encouraged the Department to actively participate in acquiring anonymous demographic data for metrics both internally and in cooperation with CAP. The Department will consider changes to its hiring practices, including having all short-listed candidates meeting with PIPA and including graduate student voices more actively in the hiring process. Additionally, a voluntary faculty, student, and staff donation program has been proposed to contribute to BIPOC-specific research scholarships.

Moving forward we are most encouraged by the formation of an EDI committee within our Department. This committee consists of a small number (2-4 each) of faculty, staff, post-doc, graduate, and undergraduate representatives, and is designed to spearhead EDI initiatives. The graduate students who sit on this committee were elected by the student body. In order to address the concern that momentum may fade as the term resumes, the committee will establish a regular newsletter to keep the department involved in the ongoing conversation about existing problems and the progress being made towards a more equitable, diverse, and inclusive environment. At this point it becomes our responsibility to acknowledge our own limitations: we are not experts in EDI. It is for this reason that MAPSA is encouraging the EDI committee and the department as a whole to work with consultants, such as the Office of Equity and Inclusion at McMaster University.

It is clear that graduate students have played a key role improving the environment of the Physics and Astronomy Department at McMaster and advocating for EDI initiatives. Part of what makes this possible is that we are in a position to see structural issues that may be invisible to faculty members. Academia is a selective system that pushes some people away and it is often difficult for faculty to see issues with the processes that have worked for them. Of course this difficulty exists for graduate students as well to a lesser extent, however not all of us pursue faculty careers. We are familiar with the university system yet still vulnerable to its flaws, and this gives us the unique perspective that has allowed us to do this work.

Despite this, graduate students face barriers that limit our ability to change the academic structures around us. First, it cannot be ignored that meaningful EDI initiatives require money. Decisions over how much money is allocated to the department or how that money is spent are made without graduate student input, even when those decisions directly impact us. The second barrier is time. Due to research and teaching commitments, many graduate students do not have time to spend organizing and participating in outreach initiatives, or engaging in necessary critical analysis of the structure that we exist within. If we are serious about improving EDI outcomes then we must do away with the idea that graduate students and faculty members are "research output machines" first and foremost, with outreach or community building done as an afterthought. An extreme push for productivity not only hinders the other important roles that we all have to play within our community, it is also an element of the environment that actively hurts people who may have responsibilities outside of academia.

Organizing has given the graduate students in the McMaster Physics and Astronomy Department a strong unified voice and allowed us to advocate for EDI and outreach initiatives and we encourage other graduate students who are reading this to form or to participate in your own representative organizations. You possess a unique and valuable perspective and you can improve academia for yourself and your peers. #ShutdownSTEM is a wakeup call to all of us to make our communities better for BIPOC. Graduate students are perfectly positioned to lead this movement, and we will accomplish positive, impactful change with collective action.

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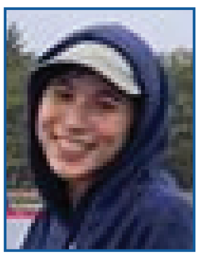
We would like to acknowledge the Physics, Astronomy, and Radiation Sciences graduate student body at McMaster University for valuable input on this article.

OVERCOMING BARRIERS TO PHYSICS: THE NEED FOR TARGETED EDUCATIONAL OUTREACH FOR NOVA SCOTIAN YOUTH

BY JOHN LINCOLN, CHARLOTTE CLEGG, TIM BARDOUILLE, AND IAN HILL



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Canada is not exempt from a racist history. In Canada, Black and Indigenous communities have been subject to systemic and institutional racism, which has contributed to unequal access to education. These restrictions date back to the 1811 Education Act passed by the Nova Scotia Legislative Assembly, which established a direct financial barrier that excluded the majority of Black Canadians from access to public education [1]. The Indian Act, passed in 1867, ultimately led to the creation of government-funded Residential Schools designed to assimilate Indigenous children [1]. Educational policies today continue to determine the academic prospects of youth in Canada, particularly along the lines of race and class [2].

Under-represented minorities (URMs) continue to experience barriers to education today, as evidenced by comparative drop-out, suspension and graduation rates relative to the total population. Nova Scotia has many Black communities with histories that precede Canadian confederation, known as African Nova Scotian (ANS) communities [2]. A 1994 study by the Black Learners' Advisory Committee (BLAC) found that 60% of ANS youth had not graduated Grade 11 [2], and as recently as 2014, only 18% of those aged 25-64 years were reported to hold a university credential (compared to 22% of all Nova Scotians) [3]. Similarly, only 13.4% of Indigenous Canadians were reported to hold a university degree in 2015 (compared to 31.4% of non-Indigenous Canadians) [4]. These effects have been shown to contribute to higher rates of unemployment, and feelings of alienation and isolation among Black-African and Indigenous communities [4].

SUMMARY

Canadians identifying as Black, Indigenous and People of Colour (BIPOC) remain under-represented in STEM fields, particularly in physics. This article demonstrates the need for educational outreach programs geared toward marginalized youth in Nova Scotia, and the role that departments and graduate students can play in further developing existing outreach materials.

SURVEY OF TARGETED EDUCATION IN NOVA SCOTIA

Recent years have seen a growth in targeted education efforts aimed at reducing educational barriers faced by Black and Indigenous learners. We focus here on major resources and initiatives available in Nova Scotia; however, this discussion is not exhaustive.

In 1970, a Transition Year Program (TYP) was established in both Halifax and Toronto. At Dalhousie, the intention of the TYP was to provide ANS and Mi'kmaq students with the academic background and financial assistance needed to complete a university degree. The year it was established, only 35 ANS students had graduated from university [5]. In 1989, the Indigenous Blacks and Mi'kmaq Initiative (IB&M) was established with the aim of increasing ANS and Mi'kmaq representation in the Dalhousie Schulich School of Law. In addition to providing financial support to participating students, the IB&M initiative contributed to improved outreach and recruitment efforts as well as increased hiring and retention of participating graduates. Over 200 participants have graduated through the IB&M initiative, increasing Black and Mi'kmaq membership among the Nova Scotia Barrister's Society from 6 and 0 before the IB&M foundation, to 79 Black members and 64 Mi'kmaq members in 2019 [6].

Beyond the IB&M and TYP, there was an additional need for programs that increase Black and Indigenous representation among Science, Technology, Engineering and Mathematics (STEM). Dr. Kevin Hewitt recognized this deficiency, and in 1999 led a one-day workshop at Simon Fraser University. Along with Wayn Hamilton and Dr. Barb Hamilton-Hinch, he would later develop the Imhotep Legacy Academy (ILA) at Dalhousie University. Since the beginning of a pilot project at Caledonia junior high-school in 2003, the ILA has expanded into a provincial outreach initiative that strives to make STEM accessible to Black youth. The ILA offers (and continues to develop) a combination of after-school programming, online activities, tutoring, mentorship and promise-scholarships to Black youth between grades 6-12. In 2019, the ILA reached over 1800 young learners, more than double its capacity in the previous year [7].

SHORT-COMINGS AND DEFICIENCIES IN CURRENT PROGRAMMING

Despite the growth in targeted education programs, Canadians identifying as Black, Indigenous and People of Colour (BIPOC) remain under-represented in Canadian universities, particularly in STEM fields. A 2015 "Report from the Committee on Aboriginal and Black/African Canadian Student Access and Retention" conducted at Dalhousie University, found that Indigenous and Black-African Canadian student enrollment remained disproportionately low compared with their representation in Canada. While Black-African and Indigenous Canadians each represent 4-5% of the total population in Canada, only 2% of Dalhousie students belonged to either of these populations [1]. In physics, Black-African and Indigenous representation is even lower [8]. The AIP National Task Force to Elevate African American Representation in Undergraduate Physics and Astronomy (TEAM-UP) undertook a two-year study to issue evidence-based recommendations for addressing the under-representation of Black-African students in physics and astronomy. The TEAM-UP report found that while the total number of physics bachelors degrees awarded by American universities had more than doubled in the last 20 years, the percentage of degrees awarded to Black-African students remained around 4% [8]. Similarly, the fraction of Indigenous bachelors degrees awarded remained below 1% [9].

The 2020 TEAM-UP report identified five factors to be influential in determining the success of Black-African students attending post-secondary education (PSE) for physics and astronomy: (1) sense of belonging, (2) a physics identity, (3) academic support, (4) personal and financial support, and (5) a supportive leadership structure [8]. Similar findings were also highlighted in the 2015 report conducted at Dalhousie University [1]. Specifically, student surveys and focus groups identified the following thematic barriers (among others) to PSE: (1) unawareness of scholarships and bursaries, (2) lack of centralized information sources, and (3) limited support and awareness in high school about university and funding opportunities [1].

OUTLINE OF THE ARTICLE

In this article we demonstrate the need for targeted outreach efforts that address these deficiencies and inspire under-represented young learners to pursue a career in STEM, with an emphasis on Physics. We begin with a structural examination of existing academic excellence programs and suggest a framework through which these can be modified to develop outreach initiatives that target marginalized BIPOC youth in Nova Scotia. We outline a pilot program to be implemented at Dalhousie University, and discuss its long-term benefits for under-represented youth, the academic community, and the province.

Summer camps as an outreach model:
It is widely understood through the success of STEM outreach programs like Shad Canada [10], and Dalhousie's SuperNOVA [11], that education is critical to empowering youth. Shad Canada is a national collaboration between academic institutions and communities, with the objective to diversify youth skillsets in STE(Arts)M and entrepreneurship [10]. The program is a month-long immersive experience on a university campus where grade 10-11 students are given opportunities to tackle real-life issues. Dalhousie's SuperNOVA has a similar objective delivered locally, however these week-long day camps are organized into specific disciplines and offered at a variety of levels between grades 1-12 [11]. While these programs have diversified their outreach initiatives, there may be additional barriers (*e.g.*, incidental costs, travel, etc.) that limit the accessibility of these programs to BIPOC youth. These programs allow prospective students to envision themselves on university campuses, one of the main tenants discussed in the TEAM-UP report [8]. To support these efforts, the physics community needs to be willing to offer their expertise to improve representation in academic departments, and more importantly, retention in fulfilling physics related careers. In physics we must demonstrate inclusion, open-mindedness, and be welcoming to all students. There is a belief that physics is "too difficult" or "only for specific people" [12]. It is imperative that these beliefs do not become barriers to entry for our field, dissuading prospective students. Having this kind of approach to recruitment will aim to address the physics-identity related aspect of the TEAM-UP report [8].

Interfacing with programs such as Shad Canada and SuperNOVA has the potential to expand the outreach of physics departments, specifically at Dalhousie. Here, we propose a short (3-5-day) research project based on a student's interest in STEM, in combination with current research at Dalhousie. We aim to give students the experience of working in a lab, understanding the necessary skill sets, and answering questions regarding pursuit of careers related to their research project. The goal would be to address the "academic support" aspect discussed in the TEAM-UP report.

PILOT PROJECT - BIPOC STEM RESEARCH PROJECT

28 BIPOC Nova Scotian students will be selected to participate in a summer research project from 7 different

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STEM labs at Dalhousie. Principal investigators (PI) and their (under)graduate students will choose/design a research project that can be performed by students in grade 11-12. Teams of 4 students will be allocated to each lab and supervised by Dalhousie (under)graduate students. Workdays will consist of students performing research tasks and preparing for a final conference style research symposium. At the end of the week students will communicate their scientific ideas to their peers, and to a panel of leaders in the field. The work that students perform for their research project and the symposium event will allow students to build peer and mentorship networks, which may facilitate their transition into an academic career. Nights will consist of community engagement exercises with youth advocacy groups, to bring forward the importance of giving back to the community. The goal here is to put STEM in a global community perspective.

In this format, we address the "supportive leadership structure" discussed in the TEAM-UP report, where the education is peer-based with support from the PI when needed. This differs from Shad and SuperNOVA programming in that we are specifically targeting BIPOC youth to empower them and address the real systemic differences in STEM, particularly concerning Black and Indigenous peoples in Canada. It should be noted that all faculty, supervisors, (under)graduate students and camp-counsellors, will be mandated to participate in anti-racist and cultural development training as an annual requirement to partake in this summer research camp.

To address the final aspect of the TEAM-UP report, we aim to fund this camp through external sources. First-stage planning efforts estimate between $7,500-10,000 in expenses for a 5-day research camp with 28 participants. These costs are based on camps with similar formats held at Dalhousie. We will be applying for external funding in the up-coming months to offer this program at no cost to participants, thereby addressing the financial barriers that may traditionally inhibit BIPOC students from attending these programs. This agrees with the Dalhousie Diversity of Nature initiative [13], a targeted experience led by women of colour, with a similar mandate.

DISCUSSION AND CONCLUSION

There are numerous potential benefits for targeted outreach in STEM fields. In this article we have discussed a pilot project at Dalhousie that applies outreach formatting that has been successful in the past. This is evidenced through Dalhousie's ILA, Shad Canada, and Dalhousie SuperNOVA programs. Enabling URM students to envision themselves in an academic setting has the potential to profoundly impact their sense of belonging and career choice. It is paramount that this benefits the student, but it inherently benefits the academic community as well. With more diverse representation in the physics community, we have better opportunities to empower a wider range of voices and perspectives. Discussed in the TEAM-UP report [8] is not only belonging but being able to identify with physics and strengthening this identity. Moreover, being able to clearly understand and articulate the importance of STEM research is important for the individual and the community.

Finally, it is important to ensure continuity of these types of outreach initiatives. Given the success that Shad Canada, and SuperNOVA have had, we are confident that effective collaboration can realize the desired continuity and community engagement. In conclusion, in effort to address systemic racism in STEM, specifically barriers to access in physics, we have detailed a pilot program that aims to empower BIPOC students through an intensive research project that will allow for skill development and networking opportunities. This program will be fully funded to address financial inequalities that may be faced with similar non-targeted youth outreach efforts.

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IMPROVING GENDER DIVERSITY AMONG PHYSICS AND ASTRONOMY FACULTY AT MCMASTER UNIVERSITY

BY CHRISTINE WILSON

The department of Physics and Astronomy at McMaster University has made significant improvements to the gender diversity of its faculty over the past 35 years. As the second woman hired in the department, I look back at how this improvement was accomplished and at some of the successes and on-going challenges.

The first woman professor, Catherine Kallin, was hired in 1986, followed by myself in 1992. Three additional women were hired in 2000 and 2001 and a fourth in 2007. Our most recent woman professor, Miranda Schmidt, was hired as a teaching-track faculty member in 2019. Our department has made excellent use of both targeted and open hires to increase its gender diversity. The hiring of 4 of our 7 women professors was enabled by NSERC's programs to support the hiring of women and/or indigenous faculty members: myself under the Women's Faculty Award program, and Fiona McNeill, Alison Sills, and Laura Parker under the University Faculty Award (UFA) program. Cecile Fradin was hired in 2001 as a Tier 2 Canada Research Chair. McMaster's spousal hiring policy was used to help retain one of our female faculty by enabling us to hire her (male) spouse.

With Dr. Kallin's retirement in July 2020, the department currently has a total of 28 faculty members, 3 on the teaching-track and 25 on the research track. Besides the 6 women professors, other axes of diversity in the department include 6 people of colour and at least 2 identifying as LBGTQ, so that approximately half of our professors are cis white men. Cecile Fradin told me "When I chose to come to McMaster, the fact that there were so many women in the department made a big difference. It really signaled the department as woman/minority friendly."

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SUMMARY

Christine Wilson is an observational astronomer whose research focuses on understanding what factors control the rate at which stars form in galaxies. Her recent focus is on galaxy mergers with extremely high star formation rates using data from the Atacama Large Millimeter/submillimeter Array.

The research of our women professors has been recognized by a variety of internal and external awards. These include 3 Canada Research Chairs, 3 NSERC Discovery Accelerator Supplements, 2 Killam Research Fellowships, and 3 Polanyi Prizes. Catherine Kallin has held Sloan, Steacie, Guggenheim and Simons fellowships. Cecile Fradin has held two very competitive awards from CIHR. I am a fellow of the Royal Society of Canada and hold the McMaster rank of Distinguished University Professor. Laura Parker holds the rank of University Scholar.

Our women professors have also taken on academic leadership roles. Within the department, women have served as Associate Chair (graduate) four times, Associate Chair (undergraduate) twice, and Acting Department Chair once. Across the university, Fiona McNeill was Chair of Medical Physics and Applied Radiation Sciences as well as Associate Vice-President (Research). Alison Sills was Associate Dean (Undergraduate) of the Faculty of Science, and both she and Laura Parker have served as President of the McMaster University Faculty Association.

One of the challenges we face as a department is that it is significantly more difficult to hire women in research areas where their representation is lower, such as quantum condensed matter or high energy physics, than it is in areas such as astronomy/astrophysics or medical/biophysics that have a higher fraction of women nationally and internationally. In the mid-2000s we made a sustained effort over 3 years to hire a woman in experimental physics using the UFA program but were ultimately unsuccessful despite identifying excellent candidates.

As individual women professors, we deal with all the (sadly) usual problems that I expect are described elsewhere in this issue: managing dual-career families, the two-body problem, and achieving a reasonable work-life balance. We are asked to serve on many committees and are promoted as candidates for administrative positions; learning to say "No" is something I personally still struggle with. Then, there is the challenge of student expectations: I cannot tell you how many times I have been in the departmental office to pick up my mail, only to have an undergraduate student assume I am a secretary. I have learned that imposter syndrome actually gets worse as I become more senior.

But there continues to be progress, both in our department and across the university. In the face of increasing evidence from studies at other universities of bias again women and BIPOC faculty, McMaster recently stopped using student course evaluations as part of determining merit awards and annual salary increases. In 2015, all women professors at McMaster were given a pay raise of $3,515 per year to boost their base salaries in order to correct for a systematic bias that had produced a significant salary differential between men and women professors. I am hopeful that it will not take another 35 years before our department matches the diversity that we see in Canadian society more broadly.

TAKING RESPONSIBILITY FOR EQUITY IN PHYSICS THROUGH PHYSICS EDUCATION RESEARCH

BY LINDSAY MAINHOOD

Objective, experimental, and scientifically pure. These are words that conventionally define the field of physics as it aims to find answers to our questions about the natural world. In current conversations (though they have been used for many decades) different words are being used to describe physics as a field of study and work: unfriendly, inequitable, and homogenous, to name a few.

A PARADOX

It seems a most interesting paradox that a field upheld by principles of impartiality is itself a rather extreme example of partiality as a community. It begs the question: *why* does physics not represent equity, diversity, and inclusion (EDI)? This is a particularly intriguing question in light of other scientific fields, similarly characterized by homogenous communities in the past, which have become increasingly diverse.

In this paper, I assert that one of the responsibilities of the physics field is equity, just as it is the responsibility of the physics field to exercise rigorous scientific methods. I discuss whether and how physics ought to take responsibility for equity; however, I preface the discussion by offering a response to the question I posed above: why does physics not represent EDI?

Importantly, this opinion article is but one response to this question, aiming to stimulate critical thinking about equity amongst the physics community (physicists, physics educators, and students of all levels). It is perhaps especially intended for those who have not yet decided how to think about their own responsibility for equity in physics. The article is inspired by recent conversations I have had with five international experts on gender equity in physics education research, who I interviewed as part of my PhD research, and from whom I have been grateful to learn.

SUMMARY

Lindsay Mainhood is a PhD candidate in the Faculty of Education at Queen's University. Her primary research interests are gender and equity in the context of physics education. Her PhD research focuses on supporting and guiding the Canadian Physics Education Research field to address gender inequities in physics education.

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WHY IS PHYSICS NOT REPRESENTED BY EDI?

From the experts on equity in physics, I gained insight on the early development of physics as a scientific field — a clue to why physics is currently failing to represent EDI. Experts spoke of the physics field as a social institution in the western context that is fundamentally non-inclusive and inequitable because it was developed by a very homogenous and exclusive group of people who were mostly white men. Using women's exclusion from the development of physics as an example, one of the experts explained: "Women were never part of defining the field, [or] what it means to be a physicist…all of those things are fundamentally inequitable and non-inclusive." They described the field of physics as one that became a "neutral, objective, rationalist kind of area, which were not the same traits people had been associating with women." The historical social dissociation of women from physics, or any person who represents an alternative to the traditional representation of a physicist, is a pattern that endures today and continues to exclude people. But why have these outdated norms continued in physics when other scientific disciplines have progressed?

The socio-historic aspects of the field of physics inform its attitudes, beliefs, and practices. These components make up its culture — the nature of which was exemplified to me when one of the experts said, "physics itself sometimes feels like an unfriendly place." This is an indication of the preservation of physics' socio-historic norms that reinforce a culture non-representative of EDI. What the experts on equity in physics observe to be sustaining this culture is a lack of care and motivation among the physics community for equity in physics: "A lot of people actually don't care, and they only care enough to make it seem like they care because, politically, you can't *not* care now." They also note the trend among the physics community to look for superficial solutions, for example: gender equity being addressed by physics educators hosting female guest speakers, discussing famous female physicists, or using more stereotypically female examples in problems.

I acknowledge that there are members of the physics community who make genuine efforts to be equitable and inclusive, who may have used such practices as part of that genuine effort. I also recognize that the physics community must be willing and must have access to practical and evidence-based recommendations for increasing EDI in teaching, supervision, and research. However, based on my conversations with the experts (and later with Canadian physics education researchers for another part of my PhD research), it seems both the physics community's willingness and access to using evidence-based recommendations are minimal, and could be inhibiting EDI progress.

One contributing factor was explained to me by one of the experts and is related to the fact that recommendations typically come from physics education research (PER). PER is a relatively young field focused on physics teaching, issues of student understanding, and more recently, affective experiences students have in physics, including those related to EDI. The challenge is, as one expert said, "physics education is in a weird place where we [physics education researchers] are fighting to be seen as competent professionals by physicists." Physics' resistance toward PER may be hindering the physics community from taking responsibility for and ultimately becoming representative of EDI. Later, I discuss how the physics community can take responsibility for equity through PER. First, I present reasons why doing so is important.

WHY SHOULD PHYSICS TAKE RESPONSIBILITY FOR EQUITY?

In a recent American Association of Physics Teachers webinar panel on making physics inclusive and equitable, one of the panelists recommended people in the physics community do the following: "Find a reason for caring about EDI, otherwise it will not happen because you won't do the work." This statement struck me with its truth; unless a sense of care or responsibility is felt for the issues, it's likely little or no investment will be made to address them. I suggest five reasons why those in the physics community ought to care about equity. I hope they encourage individual sense of care for EDI in physics in order to "do the work" that is necessary.

1. **EDI in physics can be no one else's responsibility but the physics community's.** Physicists play a critical role in the prioritization of EDI because they are at the top of the hierarchy of power and influence in their field. They affect: (*a*) the field's cultural norms, which permeate wider societal representations of the field; (*b*) the field's pursuits and outcomes in terms of research and knowledge production; and (*c*) activities of the field such as physics education and community outreach.
2. **EDI commitment allows for the possibility of redefining the physics field** by attracting a new, diverse generation of physicists who can (*a*) be prepared in light of what current physicists see as important, and (*b*) define what is valuable to the physics community in new ways. The field has an opportunity to reimagine what physics is, who physicists are, and what pathways are available to and from physics — all in service of preparing future physicists to achieve various purposes.
3. **EDI in physics is a matter of social justice.** One expert on equity in physics explained that equity is about giving people equal access to the discipline. It is "a social justice issue… allowing more people to enter this discipline both in terms of them getting access to high-status knowledge and high-status professions."
4. **Neglecting EDI thwarts physics' and individual people's capacities** for being global leaders. Contrary to the belief that focusing efforts on EDI would come at the expense of disciplinary excellence, the inclusion of diverse perspectives can enhance excellence by broadening horizons in the field and increasing the capacity for innovation.
5. **"The fact that harassment is pervasive, persistent, and pernicious.*"*** One expert explained that physics epitomizes inequity when people experience harassment. Eliminating harm done to people in physics and associated negative environments is an obvious and compelling reason for the physics community to take responsibility for EDI.

HOW SHOULD PHYSICS TAKE RESPONSIBILITY FOR EQUITY?

These suggestions represent current conversations happening around equity in physics as they are based on my discussions with international experts. Most of the experts position themselves in the PER field, where much of the physics-specific EDI work is occurring. Therefore, the suggestions describe how the physics community ought to take responsibility for equity through PER.

1. **Physicists: Engage with PER.** Because of physicists' influence and positions of power in physics, including defining physics education, the first way that the physics community can take responsibility for equity in physics is by engaging in PER. Experts reported the need to engage physicists in PER because they play an important role in improving physics education, which is the vehicle for people entering the physics community. PER is the bridge connecting physicists and education researchers, which is useful for helping each understand and fully benefit from one another's expertise.
2. **Focus PER-based EDI efforts on all levels of physics education.** PER should not only be conducted at the post-secondary level of education, where physicists work, but simultaneously at all levels of physics education from university to elementary grades. The experts say this is crucial for

creating systemic change because the issues of EDI in physics education do not begin in university; rather, they begin at the earliest levels of schooling and include socialization mechanisms outside of school.

3. **Mobilize students as drivers of change.** Experts said a key part of taking responsibility for equity in physics involves enabling physics students to help drive the changes necessary for the field to represent EDI. One expert explained that students are the least enculturated members of the physics community and therefore they see issues that faculty and even researchers may not. “Traditionally speaking, the culture is set by the people at the top, but I think the disruption will come from the bottom,” the expert said. Illustrating the power students have in numbers rather than influence, the expert believes change “is going to be driven from the bottom because [students] outnumber the top, thousands to one.” Mobilizing students enables them to change what is not working for them and what they can clearly see does not align with their wider world that demands EDI. The physics community can mobilize students by providing them with physics education experiences that turn the traditional power structures upside-down: learning with their peers in an active, communal environment that is less individualistic, less competitive, and not lecture-based. The physics community can also engage students in PER, which is beneficial for both their engagement in current issues in physics education and PER’s further development from students’ novel insights.

CONCLUSION

International experts on equity in physics say that EDI is a matter of social justice, and the continued neglect of EDI only thwarts the physics field’s and individuals’ capacities, and fails to mitigate negative environments in which harassment occurs. Commitment to EDI allows for the possibility of redefining the field of physics to not only be more equitable, inclusive, and diverse, but also more globally innovative and successful. Physicists play a crucial role in defining EDI standards in the field. Three ways that physicists and other members of the physics community can take responsibility for equity include: engaging with PER, focusing PER-based EDI efforts on all levels of physics education, and mobilizing students to help drive the change toward greater EDI in physics. I encourage readers to consider how each of us has a personal responsibility for EDI, and find a reason to care about EDI in physics — this is the first step in doing the necessary work to achieve an equitable, diverse, and inclusive physics field.

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Gender Representation in High School Physics

by Joe Muise

When I started teaching, I was surprised at the composition of my senior physics class — only five girls out of a class of twenty-five. I made it a priority to promote physics classes to girls, as I wanted more students taking physics, and a wider range of viewpoints in the conversation. As the number of girls in my classes increased, I noticed differences in the questions I was being asked, and the types of explanations I was giving, which I felt was improving the overall dialogue in the class.

WOMEN IN PHYSICS IN CANADA

In this paper, the terms girls and boys are used to represent gender expression in high school physics students. References to female and male follow the usage of those words in previous studies or data reported from provinces and territories.

Data collected in the 2016 Canadian census showed the current disparity in the representation of women in physics [1]. The report on Major Field of Study shows that just 20 percent of people identifying physics as their field also identify as female. When filtering for individuals with doctorates in physics, this number drops to 15 percent. These numbers are consistent with previous reports on women's enrollment in university physics majors in Canada — 22 percent of physics bachelor's degrees awarded in 2002 were to women [2]. In Ontario, the percentage of female students and male students in advanced math classes are approximately equal, and in grade 12 chemistry, there are more female students than male. The percentage of female students in physics trails the percentage of male students by more than 20 percent [3].

Summary

High school physics enrollment data from across Canada shows that more boys are taking physics courses than girls at both the grade 11 and grade 12 level. The STEP UP series of lessons are designed to change the culture of classrooms and to help female students identify themselves as physicists.

Several gender-dependent factors have been identified as alienating girls from physics: socialization patterns; self-efficacy towards physics; classroom culture; curriculum and assessment strategies; and teachers' beliefs and awareness regarding girls' engagement [4]. Girls are more likely than boys to report that gender negatively affects their experience in physics classes [5].

Changing high school instruction and making the classroom climate more inviting could positively affect girls, including introducing women models and mentors and raising teacher awareness regarding their beliefs about girls' participation in physics [4]. Female students have reported several positive factors influencing their decision to study physics at the upper high school level — their teachers, school science culture, family member attitudes, and peer interactions [6]. Of these, interactions with their physics teacher seems to be particularly significant to many female students who go on to study physics in college [7]. With university physics enrollment at 20% female representation, high school physics classes represent a key opportunity to make a significant impact on the number of women in physics [8].

PROVINCIAL ENROLLMENT

To understand gender representation in Canada with more granularity, all Canadian provincial and territorial ministries of education were contacted. Enrollment data for grade 11 and 12 physics courses was requested, with a breakdown by gender, as collected by the respective provinces. There is a lack of data about students who are non-binary or gender non-conforming, so we cannot know the representation for these students without further data collection. Data from eight provinces and two territories has been compiled in Table 1.

For most provinces, participation of female students is less than male students, with more of a difference in grade 12 than grade 11. Both Advanced Placement and International Baccalaureate physics courses show large gaps between female and male enrollment. With the percentage of female students in grade 12 physics trailing by as much as 30 percent in some provinces, the chances of seeing an improvement in female participation at the post-secondary level are decreased. Previously published data [9] reported the number of female and male students writing provincial examinations in several

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Table 1

The percentage of female students in physics courses at the grade 11 and 12 level for provinces and territories across the country. Jurisdictions with the female percentage less than 40% female at the grade 12 level are highlighted. Ontario's data is taken from previously published data [3]. Advanced Placement (AP) and International Baccalaureate (IB) courses data has been compiled from those provinces that provided information broken down by course (Alberta, British Columbia, Newfoundland, Nova Scotia and Saskatchewan).

Province	% Grade 11 Female	% Grade 12 Female
Alberta	41.5%	36.1%
British Columbia	42.7%	34.8%
New Brunswick	51.0%	49.1%
Newfoundland	40.3%	35.7%
Northwest Territories	46.7%	40.6%
Nova Scotia	43.5%	40.1%
Ontario	40%	34%
Prince Edward Island	45.7%	39.7%
Quebec	52.3%	48.3%
Saskatchewan	52.4%	45.8%
Yukon	47.0%	38.4%
All AP Courses		38.3%
All IB Courses	34%	31.9%

provinces. Some provinces have had modest gains in female participation, but the overall pattern is largely unchanged — there are still fewer female students than male students in high school physics. Addressing this in high school is possible using a proven method to build equitable classrooms, increase female students' physics identity and raise awareness about bias in physics — STEP UP.

STEP UP

STEP UP (Supporting Teachers to Encourage the Pursuit of Undergraduate Physics) represents a powerful movement for high school physics teachers who are motivated to support and inspire girls [10]. The project has developed guidelines for teachers along with two lessons that directly deal with the issue of representation in physics.

The *Everyday Actions Guide* is designed to develop equitable classroom culture, providing teachers with a self-reflection questionnaire to help them consider how they interact with students, and if their work promotes inclusivity in their classroom. Teachers consider whether women are taking active roles in their classes, and whether they share girls' successes and capabilities with the students' families. These reflection prompts are supported with suggestions of how teachers can support students' aspirations through their conversations with them both within and outside of the classroom. The Guide further suggests inclusive practices for facilitating group work, lab activities and whole class discussions.

The *Careers in Physics Lesson* has students explore profiles of individuals with a degree in physics and identify goals that can be accomplished with a physics degree. Students are encouraged to assess their personal values and see how they match with the values of people already working in various careers, learning that physicists are in jobs that help others and the world around them. This is completed with the help of a 2 question survey and "profile matching matrix". Critically, students are tasked with developing a "Personal Career Profile" in which they envision themselves in a future, physics-enabled career.

The *Women in Physics Lesson* examines the conditions for women in physics, drawing on current statistics and research. The goal of the lesson is to help students reflect and think critically about the issues of underrepresentation in order to counteract bias, with a focus on gender. The lesson has students examine the conditions for women in physics, discuss gender issues with respect to famous physicists, and share personal experiences. This lesson relies on teachers facilitating whole class discussions about topics which are often considered uncomfortable, and steering the conversation toward how our culture and society are represented in the field of physics — something that is not regularly discussed in Canadian physics curricula. This lesson provides discussion guidelines to help build inclusive classroom culture and enable vulnerable conversations.

The STEP UP lessons have been examined by researchers in a pilot and quasi-experimental study in the United States and are linked to improvement in students' belief in a future physics career. The STEP UP *Careers in Physics* lesson has been shown to communicate the utility of a physics degree to students [11], with girls showing higher gains in perceived utility of a physics career [12]. Teachers play an important role in getting students to see themselves as a 'physics person' [7], and both STEP UP lessons are designed to help girls develop their physics identity.

The STEP UP lesson sequence addresses the recommendations that education systems "create public awareness of gender imbalance in physics classrooms" [3], with early research into the effectiveness of the lessons showing promising results in the U.S. implementation. The lessons are also well suited to a previously identified need to change teacher attitudes about girls' engagement with physics [4]. There is tremendous potential for these lessons to change the culture of high school physics classrooms with particular benefit to those traditionally underrepresented in the field.

This academic year, my classes have nearly equal representation of girls and boys, and I'm excited to share the new Canadian STEP UP lessons with them. I hope to see more students explore the possibilities that physics can offer them. The STEP UP lessons present a great starting point for Canadian teachers to discuss equity in their classes, and help change the future of physics.

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McGill Women in Physics (WiP): Bottom up EDI

by Tami Pereg-Barnea, Hope Boyce, Carolina Cruz-Vinaccia, Daryl Haggard, Eve Lee, and Talia Martz-Oberlande

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Summary

A decade ago a group of McGill faculty organized a few events centered on women physicists to help them feel more at home in the department. The WiP initiative was met with excitement from students and support from the department. Over the years, the group assumed more responsibility, became an official departmental committee, and has recently broadened to become an EDI committee. This group testimonial describes our still-evolving history.

Our story begins around 2011 and is closely related to the changing number of women faculty in the department. Though McGill physics' first female faculty member was Dr. Ana McPherson who started her career in the 50s, there was a subsequent "drought" between 1970 and 2000. In the recent two decades, the department has hired numerous excellent women physicists, including eight who have joined the faculty in the last nine years. We are currently a department of 46 faculty with 11 women professors. The change to our department atmosphere can be felt, but not quantified. While the numbers themselves tell some of the story, we believe that the actions of our group have played an important role in reshaping the experience of our department members. We tell our story here while highlighting the initiatives taken by the McGill Women in Physics (WIP) group. We also discuss the process we have undertaken to evolve our mandate from a small WiP group to an EDI committee. We hope these narratives will benefit other departments.

EARLY DAYS

One of our authors arrived in the department as a new faculty member around 2011. Meeting with the other three female professors at the time, we felt that we should 'do something' for the female students. We thought our students might be looking to connect with other women physicists to create a sense of belonging. We also thought that while we're only four, there are many inspiring women going through our department as visitors. We therefore started the 'WiP-breakfasts'. Whenever a colloquium or seminar speaker happened to be a woman, we scheduled a breakfast gathering with her. The breakfasts were a big hit. They were advertised as highlighting the experiences of women physicists but were open to everyone. And many people came — mostly women, mostly graduate students. It was clear that the students were craving a network and ways to feel welcome in the department. Many volunteered to help and within a few weeks the operation was run exclusively by volunteer graduate students.

FORMING STRUCTURE

It must have been an unusual sight for our colleagues to walk into the staff lounge and find a group of 20-30 women discussing their research, their lives and anything in between. The responses were mostly supportive, and importantly, the department chair embraced and encouraged our efforts. Another new faculty member took over the breakfast club and formed the WiP committee. The committee was made up of herself and a dedicated team of students, both graduate and undergraduate. Within a year the WiP committee became an official committee of the department, and it was now up to the chair to nominate the faculty committee members who then recruited student members. Moreover, this was recognized and counted as service work for the faculty. A couple of years later we asked for and received a paid position with salary equivalent to a standard teaching assistantship and from then on a graduate student was selected as the committee's coordinator. These structural differences were the department's way of showing support and allowed us to devote more time to this work and to broaden our scope.

GROWING INITIATIVES AND ACTIVITIES

A burst of new activities came with the new structure. This has many axes, but in broad strokes can be divided into in-reach and out-reach. The first of these aims to continue making the department a more equitable and inclusive environment, while the second aims to encourage young women to join the sciences.

Inreach: social events — We continued our WiP breakfasts and other events and even engaged the whole physics community through a pub crawl, where discounted drinks at bars around the McGill area were given to 'I love WiP' t-shirt wearers.

Inreach: education — We know that creating a better environment takes all of us. But is our community aware of implicit bias? Imposter syndrome? How stereotypes affect one's behaviour? We invited EDI experts to talk to the department. Importantly, this was done as part of the physics colloquium series, and for the past few years, a special EDI colloquium has been presented annually. Our first speaker has written her own article in this issue (see Allison Gonsalves's paper)!

Another educational activity was the creation of the WiP "Equity Lending Library", situated on a few shelves in the staff lounge. Moreover, physics-department focused EDI workshops were organized separately for students, staff and faculty. The workshops have been offered by McGill's equity office, covering topics such as "Becoming an Active Bystander", "Equity 101", and "Employment Equity". All of these workshops are available through other channels at McGill, but bringing them into the physics building made it easier to attract the physics audience and we enjoyed broader participation at all career levels.

In addition to the workshops, our members were also requesting a forum in which to have more regular discussions about issues at the intersection of EDI and education. The McGill Space institute, a research center closely affiliated with the department of Physics, had a weekly Education, Public Outreach, and Diversity (EPOD) discussion group. It had been running for a couple of years. In collaboration with members of the WiP committee EPOD broadened both its scope and its audience. Not only is it now open to members of the Physics department from fields beyond astrophysics, but it also discusses a broader range of topics. EPOD is meant to give people a space in which to learn about and talk about how EDI issues intersect with academia and education. It's also a forum in which to source best practices towards making the department a more inclusive and welcoming space for underrepresented groups.

We have also begun to work on making our space more welcoming. Our walls were decorated with pictures of past distinguished public lecturers. None were women, none were Black … you get it, the usual non-diverse roster. We purchased the 'Beyond Curie' series of posters Amanda Phingbodhipakkiya, framed them and added them to our decoration.

Inreach: EDI policies — With volunteers and coordinators we felt it was time to tackle another problem. While the Quebec government and McGill provide a generous parental leave to its employees, students who become parents do not have any guaranteed support. We therefore started to study the issue and found that funding agencies can provide parental leave payments to students who are paid through a scholarship or a grant. This was not known broadly, at least not in our department. Moreover, in some cases the students were not eligible. Together with the department chair we wrote a policy that ensures coverage — either by the funding agencies or through departmental funds. The policy is advertised on our website.

Outreach: education — Our department does not exist in a bubble: stereotypes and bias are internalized early in life [1], prior to joining our department. We have teamed up with Dr. Gonsalves from the McGill Department of Education to design 90-120 minute seminars on topics of EDI for local secondary colleges. These sessions each serve 10 to 200 students and some staff and faculty. Paid graduate physics students offer peer-to-peer discussions on explanations of discrimination in physics and STEM, equality versus equity, imposter syndrome, stereotyping, and biases. By engaging students in discussions on social issues within the physics community early on, students feel less isolated in this field [2,3]. We offer repeat seminars as well as panel discussions, which bring physicists in different careers to share their experiences in the field and answer students' questions. Surveys conducted with our audiences show an improvement in EDI knowledge and interest in physics careers.

Outreach: Women in Physics Canada (WIPC) Conference — In June 2019 our department hosted the 8th edition of WIPC, attracting 147 participants to Montréal for three days of science exchange and connection. The main objective of this edition was to support and encourage junior physicists who identify as a gender minority or underrepresented group to persist in the field. Led by a team of graduate students supported by our department staff, the organization took an intersectional approach, centering conversations about mental health in academia, the LGBTQI+ climate in STEM, justice and equity in physics, and promoting a field inclusive to identities beyond the gender binary. In addition to featuring scientific presentations by leaders in physics, junior scientists, and students, we provided networking opportunities in the form of regular breaks and meals catered from local vendors with sustainable practices. Feedback from participants was overwhelmingly positive, with majority of respondents commenting that they felt a sense of community, found the environment welcoming, and appreciated the schedule for its balance between science and equity content.

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EXPANDING OUR MISSION AND SUBSEQUENT ACTIVITIES

In recent years, there was growing concern within the committee that there were other underrepresented groups in the department that couldn't be adequately represented or advocated for under the umbrella of "women in physics". Not all minority members of the physics department identify as women, and self-identified women are also diverse along other axes (*e.g.*, race and ethnicity, sexual orientation, etc.). Thus began a discussion of whether, and how, to broaden both the mandate and the demographic composition of the committee, while also taking care to not diminish the role that WiP plays as a community and a counterspace for women in the department. Concerns were wide-ranging: Would women in the department lose the leverage they had worked hard to establish? Would the camaraderie and respectful discourse within the committee diminish if its composition changed? Would we become overwhelmed by attempting too many difficult undertakings and become less effective, not really serving all or any marginalized groups? To tackle these wide-ranging concerns, we invited Shanice Yarde, one of the Equity Educators from the McGill Provost's Office to moderate and guide two extended conversations with our committee and most active volunteers. The moderator used her expertise to help us voice our concerns as well as our hopes and to explore various options for change and growth. We emerged from these discussions with a strong sense that our advocacy should encompass a wider intersection of issues and departmental concerns and that we should begin work to transition the committee from focusing on women in physics to advocating for equity and inclusion in physics. In June of 2020, the EDI committee was formally created.

Climate survey — In an attempt to check the temperature of the entire department in an anonymous fashion, a group of students, postdoctoral researchers, staff, and faculty joined together to run a departmental climate survey for Summer 2020. The goal was to better understand how identity affects people's experiences in the department. The hope is that by running regular surveys in the upcoming years, we will be able to make informed programmatic decisions and be more accountable to the physics department community.

Best practices — Spurred by discussions within the department and at the WIP Conference at McGill, in 2019 a group of students set out to formulate Best Practices for the department to adopt. The goal of the document is to provide concrete recommendations for action and learning to be organized so that department members can access sections based on one's role in the department (*e.g.,* committee chair, individuals). In parallel to the development of the code of conduct and department values statement (see below) this best practices document is evolving and informing the prioritization of actions items for our community.

New departmental statement – Galvanized by the tragic death of George Floyd, the department was called upon by our students to take action. The EDI committee, with the full support

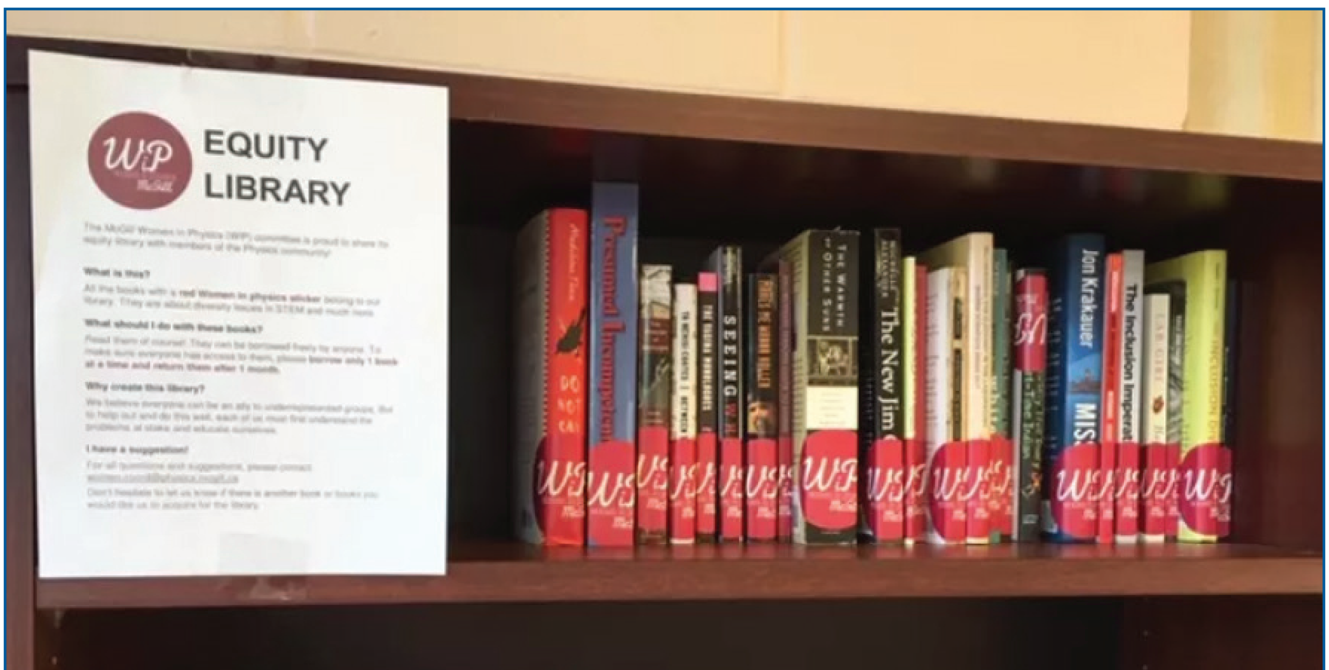

Fig. 1. Equity library in the physics staff lounge.

of the chair of the department, drafted and published McGill Physics Community Statement against Racism on June 9th 2020. On the next day, the department joined #ShutDownSTEM and #ShutDownAcademia to educate ourselves on the prevailing systemic racism in the physics community and to reflect on what needs to be done to make our department more diverse and inclusive. Town hall meetings, organized by a member of the EDI committee, were extremely well-attended with approximately 100 people in the audience across a wide cross-section of the department including students, postdoctoral fellows, and faculty members. Our discussions were framed around how our department stands with respect to the list of suggestions made by the TEAM-UP report from American Institute of Physics. After the meetings, the committee solicited suggestions from everyone on how to facilitate a sense of belonging, help build physics identity, and provide academic and personal support for under-represented minorities. We received overwhelming support with more than 5.5 letter pages worth of suggestions. One of the action items that we immediately tackled was drafting a permanent values statement and code of conduct for the department. With the help of over 30 volunteers of students, postdoctoral fellows, and faculty members, first drafts were completed within a month and were shared with the rest of the department for open feedback. A revision is currently underway. In parallel, the same group of 30 volunteers are drafting a prioritized list of action items, identifying each of their goals, metric of success, required resource, and the responsible party in the department.

OUR EDI COMMITTEE GOING FORWARD

While our story ends here, our journey does not. We aim to provide resources and initiatives to the department and feel equipped to do so. However, it takes more than a committee to make a real change. Improving the work culture and climate requires the expertise, support and effort from every member of the department. We are encouraged and heartened by the outpouring support thus far from many of our colleagues, as well as their dedication to support each other and to promote the diversity of our future physics communities. It is our hope and vision that through continued EDI work that includes the voices and participation of all members of the department, we will together make our community a better place for everyone.

THE CONTRIBUTIONS OF SELF-EFFICACY AND TEST ANXIETY TO PHYSICS EXAM "GENDER GAPS"

BY JARED B. STANG, EMILY ALTIERE, PATRICK J. DUBOIS, YULIA EGOROVA, CHRISTINE GOEDHART, JOSS IVES, KAREN M. SMITH AND JACLYN J. STEWART

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Women are underrepresented relative to men in science, technology, engineering, and mathematics (STEM) in Canada [1]. The demographic make-up of post-secondary STEM students skews toward men — particularly in physics [2] — and there was also found a gap in the retention of first-year women in STEM programs from 2010–2015, with 66% of women persisting compared to 72% of men [1]. These imbalances are unjust and they ultimately reduce the quality of physics work in Canada [3].

The question of what contributes to this gender imbalance is complex, however, symptoms of inequities can be found. Prior to the study reported here, author J.B.S. compiled exam score and gender data across four introductory physics courses at the University of British Columbia (UBC), comprising more than 2500 engineering, science, and non-science students. There was a consistent difference — between 2% and 7% — in the exam scores in favour of men. This type of "gender gap" in assessment scores in has also been reported for research-validated concept inventories at Canadian universities [4,5] and in the wider Physics Education Research community [6]. The widespread nature of the gaps in assessment scores provides evidence that gender-based inequities permeate physics education. Admission to undergraduate programs, scholarships, and obtainment of research experience depends on grades, and these inequities in grading may exclude more women than men. However, a focus on exam scores cannot explain why the differences exist or give any suggestions to instructors looking to counteract this phenomenon. In this article, we explore two psychological factors which may contribute to gender-based differences in exam scores.

SUMMARY

We show that in our active-learning introductory physics course both physics self-efficacy and test anxiety may contribute to gender-based disparities in assessment scores.

Self-efficacy is the belief in one's capabilities to complete a particular task. This is an important construct because it influences the choices a person makes and the effort they will put into a task [7]. Recent reviews show that in general, women enter STEM programs with lower self-efficacy [8], and in particular report lower levels of physics self-efficacy than men [9]. Self-efficacy has also been shown to be related to performance [10,11] and persistence [12] in physics. Test anxiety is the tendency to become anxious in a high-stakes testing situation. If one group overall experiences higher levels of test anxiety, this may impair the performance of that group on exams, creating a disadvantage. Test anxiety has been shown to mediate performance for women — but not men — in an introductory biology course [13] and, more recently, across science courses [14].

We examine the physics self-efficacy and test anxiety reported by students in our introductory algebra-based physics course, and the relationship of these to exam scores. The study shared here is a preliminary step toward better understanding more aspects of the student experience in our physics course. The wider aim of this program of research is to identify the relevant affective factors, and their causes, to make concrete suggestions about how to make physics education more inclusive.

MEASURING STUDENT PERFORMANCE, SELF-EFFICACY, AND TEST ANXIETY

This study took place in a grade-12 equivalent introductory physics course at the UBC Vancouver campus. The course was taught using active-learning techniques, including personal response "clicker" questions and worksheet activities. The approximately 800 students were enrolled across three lecture sections, each taught by a white male instructor.

Even though less than 1% of students taking this course go on to do a physics degree, the results from this study are important to the goal of increasing the participation of women in physics for several reasons. First, these students are members of the wider civic community and their experiences in physics and science will impact how they participate now and in the future. Second, addressing inequities across all the courses we teach is an important way to help shift the culture of physics towards more inclusion. Finally, the trends shown here may be applicable to courses for physics majors, helping us to understand why students who begin in the field do not persist.

For this study, we used course performance data, data from an administered diagnostic test and affective and demographic data collected through surveys. The design was informed by a pilot study whose results are presented in Ref. 15. A total of 622 unique participants responded to our demographic survey. Although the survey contained many items, we focus here on our gender identity question, for which 170 students selected "Man" and 444 students selected "Woman". Because of the insufficient sample size, students who self-identified as members of other gender identity groups were excluded from the analysis presented here. We aspire to incorporate the experience of those identifying as non-binary persons in future work. To measure the incoming physics knowledge of our students, we used the Force Concept Inventory, a well-established diagnostic survey measuring the degree to which a person has a Newtonian view of mechanics concepts. To assess students' self-efficacy and test anxiety, we administered an affective survey with questions derived originally as a subset of the Motivated Strategies for Learning Questionnaire (MSLQ) [16]. The survey items were presented using a 7-point scale with options ranging from "strongly disagree" to "strongly agree". Responses to each item were translated to a numerical scale, and the items within each construct were averaged to get values for each student's self-efficacy and test anxiety. Performance data came in the form of grades from the final exam, which consisted of 15 multiple choice questions and 5 multi-part open-response problems.

Our multiple linear regression model for predicting final exam score was chosen in advance of analyzing these data, and used gender identity, self-efficacy, test anxiety, and FCI score as predictor variables. For the regression model, all variables were standardized to have means of zero and standard deviations of one.

SELF-EFFICACY AND TEST ANXIETY DISPARITIES AND THEIR RELATION TO EXAM SCORES

Women had lower self-efficacy, higher test anxiety, and lower FCI scores, while the final exam scores show no differences by gender identity (see Fig. 1). Although the exam scores did not show a significant difference this year — in contrast to both the pilot study and the informal data collection that inspired this study — building a regression model allows us to see how self-efficacy and test anxiety are related to exam scores, which may help us understand the gender-based differences that typically appear.

The model to predict the final exam score, with the numerical regression coefficients, looks as follows,

$$\text{final exam} \sim 0.29 \times \text{gender identity} + 0.26 \times \text{self-efficacy} - 0.14 \times \text{test anxiety} + 0.33 \times \text{pre-FCI},$$

where all four regression coefficients are significant at or beyond the $p < .01$ level. The fraction of the total variance in the final exam scores explained by this model is $R^2 = .32$.

This model shows that higher self-efficacy is associated with a higher final exam score while higher test anxiety is associated with a lower final exam score. The coefficient for self-efficacy in the linear model is larger than that for test anxiety and the mean difference between women and men in self-efficacy is larger than the mean difference in test anxiety. This suggests that self-efficacy may play a larger role in gender-based disparities on assessments than test anxiety. This is consistent with the pilot study, where test anxiety did not improve the explanatory power of the models considered. While there was no raw gender-based difference in mean exam scores, the model predicts that for students with identical self-efficacy, test anxiety, and FCI score, women will perform better than men on the final exam by 0.29 standard deviations (or about 5%). This is an encouraging trend which suggests that, in this course, initial performance disparities as measured by the FCI are either not appearing in or tending to even out by the final exam.

The predictive value of physics self-efficacy suggests that attending to self-efficacy through facilitation and curriculum has the potential to improve equity in the classroom. Kalendar *et al.* [11] summarize some approaches that an instructor might consider, such as: making sure that equity and inclusion are part of the course design, including explicitly valuing contributions from all students; assigning roles in group work to reduce unbalanced participation; and fostering a growth mindset so that students view challenges as learning opportunities. Earlier work by Sawtelle [17] identifies that certain classroom components — including cooperative group work, instruction focused on physics model development and use, and instructor interaction — are mechanisms through which the physics self-efficacy of students may be positively impacted. However, in their recent review, Henderson *et al.* [9] point out that there is a deficit of evidence describing classrooms which successfully bolster the self-efficacy of students (and women in particular). Given the demonstrated potential for self-efficacy to improve the learning and performance of all students, there is a need for teaching innovation and further research focused on this aspect of the student experience.

Test anxiety had a negative impact on exam scores, and women reported a higher level of test anxiety than men in our study, suggesting that strategies to mitigate test anxiety may be one path toward a more equitable classroom. Ballen *et al.* [13] and Salehi *et al.* [14] are in agreement that rethinking

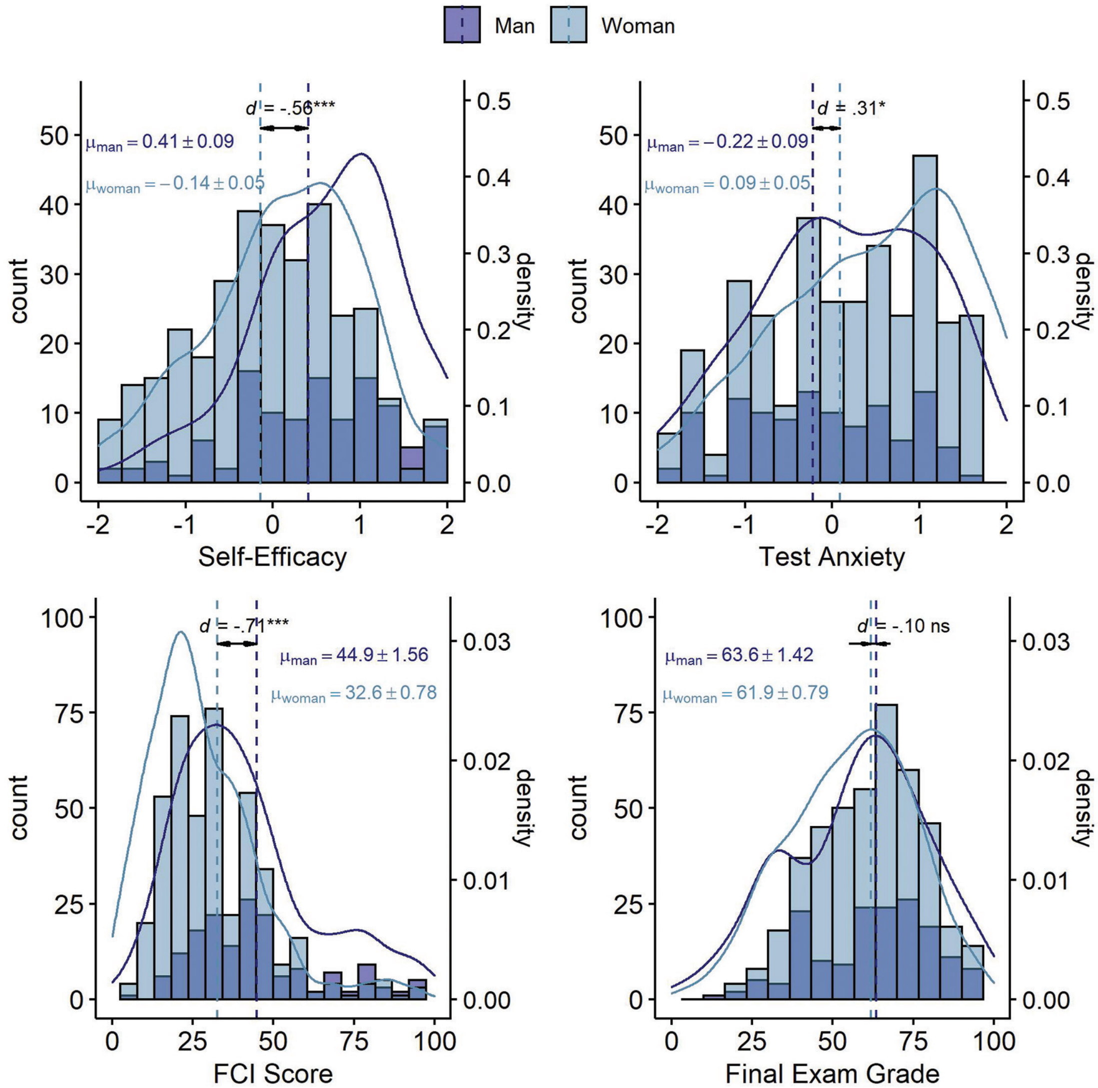

Fig. 1. Histograms and overlaid density plots comparing the distributions of women and men on self-efficacy, test anxiety, incoming FCI score, and final exam grade. Self-efficacy and test anxiety have been standardized while the FCI and final exam grades are on a percentage scale. Means and standard error in the means are indicated for the two gender identity groups on each panel, and the effect size Cohen's d for the difference between men and women is shown. Statistical significance is evaluated using a two-tailed t-test assuming unequal variance and using an $n = 5$ Bonferroni correction for multiple comparisons (including a comparison of end-of-term FCI scores not presented here). ns: not significant; *: $p < .01$; **: $p < .002$; ***: $p < .0002$.

assessment strategies — including devaluing high-stakes exams in favour of multiple lower-stakes and mixed assessment types — is the most promising approach to reducing the possible negative and biased impact of test anxiety. Harris *et al.* [18] recently reported that a combination of interventions designed to reduce test anxiety did not reduce reported levels of test anxiety, but did improve exam scores for all students. Unfortunately, in their study, the gender gap in exam scores persisted. As for self-efficacy, more work is needed to better understand what spaces and practices allow students to learn and demonstrate their mastery without the negative effects of test anxiety.

CONCLUSION

This study provides evidence that addressing self-efficacy and test anxiety disparities may be mechanisms to promote equity in the physics classroom. The overall effect of test anxiety on exam scores was smaller than that of self-efficacy in both our pilot study and the data presented here. However, as Madsen *et al.* [6] describe, "the gender gap is most likely due to the combination of many small factors rather than any one factor that can easily be modified." Therefore, all factors should be considered in the pursuit of an equitable classroom environment. In future work, we will include other constructs which have been shown to be important for student achievement and persistence in STEM, such as sense of belonging and science identity [19].

We have presented here data relevant to the wider issue of participation inequities in physics in Canada. Since exam and course scores impact the opportunities available to students and the future choices they make, gender-based disparities in these scores very likely contribute to the overall participation differences. Better understanding how students experience our classrooms by attending to affective dimensions such as self-efficacy and test anxiety can reveal mechanisms responsible for the inequities we observe and, ultimately, help to create classroom environments that are inclusive for all students.

ACKNOWLEDGEMENTS

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LASSONDE LAUNCHES THE HELEN CARSWELL STEAM PROGRAM FOR WOMEN – SUMMER 2019

BY ALLAN CARSWELL

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The Lassonde School of Engineering welcomed 30 high school girls to participate in a 4-week program of paid research opportunities doing meaningful work in STEAM (Science, Technology, Engineering, Arts, and Math).

The Helen Carswell STEAM Program for Women (previously known as the Summer Research & Mentorship Program) was made possible thanks to a generous gift from the Carswell Family Foundation. This year the program takes on a new name and identity, honouring Helen Aird Carswell, an exemplary leader in STEAM.

Helen was a registered nurse by trade who demonstrated an entrepreneurial spirit. Most notably in 1974, Helen co-founded Optech Inc. with her husband Allan I. Carswell. Today, Teledyne Optech is a world leader in the high-tech lasers with systems on all seven continents, in space, and on the surface of Mars.

Throughout her life, Helen has been active in the arts, playing piano and the violin and singing for many years. She dedicated much of her community service and philanthropic affairs to supporting arts-based programs. The Helen Carswell STEAM Program for Women marks an exciting new development in Lassonde's commitment to advancing equity, diversity, and inclusion in STEAM.

During the opening ceremony, the participating high school girls had the opportunity to hear personal stories from Dean Jane Goodyer and Dr. Allan Carswell. They also heard from program alumnus, Ishleen Kaur, who will be starting her undergraduate journey at Lassonde this fall. The new program design was also unveiled during the ceremony. The colourful design treatment embodies the diversity of the program and connections the girls will make throughout the summer.

Over the course of 4-weeks, the girls in the program explored the various facets of STEAM through workshops, artistic activities, and working with Lassonde faculty members on their cutting-edge research. Workshop highlights included a presentation from Association of Ontario Land Surveyors (AOLS), a geocaching scavenger hunt with Professor Mojgan Jadidi, and the Hello Café, hosted by Dean Goodyer. Hello Café is a series of creative problem-solving workshops that encourage girls to think about issues that affect the daily lives of people around the world. The initiative supports young girls to open their minds, create opportunities, and gain confidence to help those around them.

The high school students worked within the framework of the United Nations' Sustainable Development Goals in their research to address global challenges related to poverty, inequality, climate, environmental degradation, prosperity, and peace and justice.

The girls received guidance from current Lassonde student mentors throughout the program. Mentor support will continue after the program's completion, providing the high school students with additional guidance as they explore their future education and career pathways.

Program support was continued for the third year by the Association of Ontario Land Surveyors (AOLS). Thanks to their donation, participants gained exposure to the Geomatics program and related career opportunities. Support was also provided by the Canada Summer Jobs Program.

The Helen Carswell STEAM Program for Women concluded on August 2, culminating in a poster presentation showcasing the girls' research contributions. Throughout the 4-week program they contributed to a variety of research projects ranging from water sanitation to sustainable alternatives to cement and metal. The program closed with the presentation of a collaborative art installation demonstrating each participant's journey and commitment to their UN Sustainable Development Goal.

"I am thrilled at the success of the Helen Carswell STEAM Program for Women. Outreach programs, like this one, support our commitment to encouraging as many young women as possible to consider a career in engineering. By focusing on the United Nations' Sustainable Development Goals, our participants were able to see the social impact engineering and science can have on the world and the results their dedicated efforts can have in generating that impact. The four-week program was nothing short of inspiring," Dean Jane Goodyer said of the program.

For more information on the Helen Carswell STEAM Program for Women, please email outreach@lassonde.yorku.ca

TURNING TABLES IN PHYSICS: UTILIZING PHOTO-RESEARCH EXHIBITS TO CHALLENGE INEQUITIES AND CELEBRATE WOMEN IN SCIENCE

BY EDEN HENNESSEY, SHOHINI GHOSE AND ADRIANNA TASSONE

What does it mean to be 'at the table' in science? The table itself is a work surface and a physical object, but is also known in Western cultures as a place of power where academic, economic, political, and cultural decisions are made. As a metaphor for inclusion in science, one could say that women in science, and in physics specifically, have been historically absent from the table. Embodying this absence, in 2018 Donna Strickland became only the third woman to ever win the Nobel Prize in physics and the first Canadian woman to receive this designation [1] in 117 years.

Women's underrepresentation in science education in Canada also reflects a disparity; 2016 data from the census showed that women comprised just 34% of Bachelor's degree graduates in science, technology, engineering, and math (STEM), and only 23% of Canada's science and technology workforce [2]. A dearth of women science students leads to predictable shortages of women in science professions; the Canadian Association of University Teachers reported that in 2010, just 2.4% of physics faculty members were women [3]. Due to a lack of systemically collected and reliable data, we cannot yet fully articulate Canadian statistics for women in physics, however, surveys from the Canadian Association of Physicists (CAP) showed that from 2014 to 2016, the number of women physics faculty members has remained at just 16% [4]. Data from the United States show that women's underrepresentation in physics is not unique to the Canadian context. In 2014, women occupied only 10% of full professor positions, whereas 16% of physics faculty members and 19% of astronomy faculty members were women [5]. In 2016, only 26% of newly hired physics faculty members and 40% of newly hired astronomy faculty members were women [5].

SUMMARY

What does it mean to turn tables in Physics? This educational manuscript discusses a photo-research exhibit (#TurningTablesinSTEM) featuring portraits of women in science paired with research and personal stories. Portraying Physicists in an accessible, provocative way can promote dialogue among scientists about who is represented in Physics and who is not.

It is also important to recognize that statistics about women in physics are not always reflective of the intersectional identities that exist in reality (*i.e.,* interactions of different marginalized identities resulting in greater oppression such as race, ethnicity, sexual orientation, creed [6]. For instance, data from the United States shows that Black and Hispanic women are still underrepresented in physics and astronomy, however, representation of Hispanic women is increasing over time, whereas the representation of Black women has not improved [5]. Perhaps most indicative of the shortage of demographically diverse women in physics is the fact that to date, a search of Canadian physics departments across Canada shows not even one Black woman holding a tenured faculty position. Not surprisingly, a lack of representation translates into a lack of acknowledgement and awareness of who 'does science.'

Illustrating this point, a recent poll of Canadians showed that 52% of respondents said they could not name a single woman in science or engineering [7-8]. Furthermore, in the same survey, 77% of respondents agreed that more media representation of women in science careers or leadership roles could help lessen the gender gap in science [8]. Indeed, one way to raise awareness of these continued disparities is to mobilize knowledge about women's underrepresentation in science roles. However, it is critical to note that interventions aimed at raising awareness of gender disparities in science can also have unintended consequences, such as decreasing women's sense of belonging because such interventions focus on discriminatory experiences, inducing identity threat [9]. Given that previous research has suggested that increasing a sense of belonging can be an effective tool for retaining underrepresented scientists (*e.g.,* Black physicists; [10]), knowledge mobilization must also consider ways to increase awareness while not simultaneously decreasing this sense of belonging

One such method of sharing knowledge about biases in science is through a unique mobilization method called

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photo-research exhibits. Photo-voice methodology is a method in which research subjects take photos themselves that are presented with narratives [11-12]. Using a different approach, photo-research exhibits present compelling visual images featuring girls and women in science accompanied by empirical literature interwoven with personal narratives. Two initial photo-research exhibits (#DistractinglySexist, #DistractinglyHonest) were immensely well-received by observers including students, educators, researchers, scientists, parents and community members [13]. Preliminary data also showed benefits for the featured scientists, who noted important connections forged with other women in science during the project [13]. Importantly, literature from social science asserts that social support, mentoring and science identification can be key factors in retaining women and girls in science [14].

Knowing that photo-research methods were associated with positive outcomes and increased outreach [13], a third exhibit was designed to further emphasize the role of the subjects in creating the images and choosing the supporting literature and narrative. Drawing on participatory action research (PAR:[15]), in the newest exhibit, the subjects were invited to be co-creators of the pieces. They were asked to (1) identify a concept or message related to their scientific work, (2) collaborate in designing images, and (3) provide input on which research would accompany the images. In doing so, the goal was to produce a photo-research exhibit in which girls and women in science could take an active role in crafting images and narratives, better reflecting the voices and experiences of the individuals involved.

#TurningTablesInSTEM

The newest photo-research exhibit titled '#TurningTablesInSTEM' celebrates girls and women in STEM spanning nine decades of experience, all photographed at the same table. The exhibit was developed in partnership with the Laurier Centre for Women in Science (WinS). Participants were invited to be featured using existing networks, with the goal of recruiting a scientifically and demographically diverse sample. The exhibit features 14 aspiring and/or established scientists in a wide range of scientific fields including physics, biology, zoology, chemistry, engineering, and social science. As in previous collaborations, celebrated photographer Hilary Gauld ensured a high-production value. For the purposes of this paper, three pieces from this exhibit featuring physicists will be described.

A PHYSICS EDUCATOR SEEKING CLARITY AT THE TABLE

Lisa Cole is a physics and mathematics educator who chose to depict an image conveying her vision for a future of physics education. The image (See Fig. 1) was accompanied by the following text, articulating both her personal story and incorporating studies from social science and education:

As students in science, we often start at the drawing table. That is, we start without much expertise and are instead driven by passion and curiosity. At different stages of the scientific journey, it can be difficult to see where a career in science can take you. This is where science educators like Lisa Cole play a pivotal role in creating a clear vision for the future of science education. Lisa is an award-winning physics educator, known for her enthusiastic instruction and ability to inspire students and educators. Her vision for the future of STEM education is one that emphasizes creating opportunities to explore different interests, and one that includes all students actively shaping their journey towards scientific self-discovery. Research shows that implementing programs to promote inclusive learning environments benefit student learning, and instructors' attitudes in science [16]. Given girls as young as 6 years old are less likely than boys to believe members of their gender group are brilliant [17], it is clear that we must establish inclusion early in the classroom context as a way to attract, diversify and retain the most scientific talent.

Fig. 1 Lisa Cole in the image titled 'Seeking Clarity at the Table'.

In short, in this image readers learn about how physics educators can be instrumental in inspiring all students to pursue physics. Given research shows that a growth versus fixed mindset (*i.e.,* believing one's identity and abilities can change over time; [18]) benefits girls and women in science [19], the role of educators in cultivating creativity and a growth mindset in physics should be communicated broadly.

AN ARTIST AND A PHYSICIST: STEAM TEAM AT THE TABLE

Mayar Tharowat Mohamed is a graduate student in physics and a visual artist. This image (See Fig. 2) features Mayar alongside fellow scientist and actor, Hiba El Miari. The image is paired with literature on the apparent mismatch between science and art perceived by many [20]. This image speaks to an evolving definition of the acronym STEM to include 'arts' making the

Fig. 2 Mayar Tharowat and Hiba El Miari in the image titled 'STEAM Team at the Table'.

new acronym STEAM. The following text accompanied this image, combining personal narrative of the featured subjects with studies on gender stereotypes and different identities:

> *STEM and STEAM – you might have recently encountered these acronyms that are often used to describe science, technology, engineering, arts, and math. Interestingly, adding the 'a' to STEM could change how people think about science as a stereotypically masculine profession. Indeed, according to Nosek et al. [20], people tend to implicitly associate science with men and arts with women. What are the consequences of holding such associations? It is possible that such associations could affect behavior; research shows that some female scientists avoid overtly feminine practices or gender displays (e.g., make-up, high heels) to avoid being seen as 'less scientific' [21-22]. Furthermore, the extent to which science is perceived as 'creative' affects men's and women's choices differently; for women (but not men) the more science and creativity are associated, the more women are interested in scientific careers [23]. Mayar is a skilled physicist, who is also a gifted artist. Hiba is a knowledgeable biologist, who is also a dancer and actor. By combining passions for science and the arts, it is possible that Hiba and Mayar will experience greater success; research suggests that integrating arts into sciences can unleash potential to foster creativity and STEM innovation [24]. Moreover, their friendship models how women can support other women in their scientific journeys — in fact, a shared social identity as women in science may increase their likelihood of pursuing science careers [14]. It is increasingly important that scientists communicate their work; integration of the arts is one potential avenue for doing so while also promoting public engagement with scientific and social issues.*

In this image the reader learns about how sciences and arts are often associated with specific gender identities, however, the subjects within the image defy this association by doing both arts and sciences. In line with recent efforts to promote interdisciplinary collaboration by federal funding agencies (*e.g.,* [25]), this image encourages observers to perceive art and science as positively related instead of opposing or mutually exclusive fields. Furthermore, research from social and organizational psychology shows that diversity in groups is positively associated with employee creativity, efficiency, and quality [26-30]. Future physics and science outreach and research should further explore how diversity of field as well as demographic diversity relates to attraction and retention of underrepresented groups.

A PHYSICIST DISCUSSING UNCERTAINTY AT THE TABLE

Kristine Boone, a PhD Candidate at the Institute for Quantum Computing chose to portray a common dilemma facing physics and science students; whether to pursue an academic career or a career in industry. This visual was designed as a play on words, drawing a parallel with the uncertainty experienced by physics students with Heisenberg's Uncertainty Principle, which describes the uncertainty of a particle's momentum and position. To portray this parallel, the table is tilted 45 degrees, reflecting a teeter-totter of hypothetical indeterminacy in position and momentum. The dice that Kristine tosses also emphasizes this theme. The following text accompanied the image, articulating the uncertainty that students might experience when deciding on a career path in physics:

> *Imagine that you have just finished years of training in your scientific field. What's next? For many people in science, the path after finishing school is uncertain. On the one hand, you can choose to pursue a career as an academic scientist, and spend most of your time writing grant applications, supervising students, and publishing papers. On the other hand, you can choose to pursue a career in industry or government, where you spend much of your time applying the skills gained in graduate school to a real-world context. For some, the choice between academia and industry is easy, whereas for others, it is a difficult one. Some scholars have produced*

Fig. 3 Kristine Boone in the image titled 'Uncertainty at the Table.'

recommendations to help students decide what path is right for them [31]. There is some evidence that most people do not pursue an academic career after graduate school — just 1 in 5 PhDs in Canada will become a professor, whereas most pursue careers in industry, business, and government [32]. For Kristine Boone, who studies quantum computing, the choice between a career in academia and industry was not easy. According to the principle of quantum uncertainty, you can never simultaneously know the exact position and the exact speed of an object because everything in the universe acts like a particle and a wave at the same time. For scientists, it is challenging to decide if you will be more satisfied with a career in academia or in industry, especially because they both have some benefits and also some drawbacks. Kristine has chosen to pursue a career in industry wherein she will certainly continue to succeed in quantum science.

This image and text together connect a physics concept with a real-world phenomenon that may be familiar to physics students. Given research shows that from 1971 to 2011, American female physics majors were increasingly likely to report being undecided about career choices [33], it is crucial to normalize discussions of such uncertainty.

CONCLUSIONS

Photo-research exhibits can be utilized to give girls and women in physics a platform from which they can tell their stories in an empowered and engaging way, supported by empirical research evidence. In doing so, exhibits such as #TurningTablesinSTEM challenge us to think about who is represented in physics, including how and why. To date, the exhibit has been displayed to thousands of people in Canada, for example, appearing at the Ontario Science Centre in celebration of the International Day of Women and Girls in Science.

What does it mean to turn the tables in physics or in science? In line with empirical work showing the continued scarcity of women in physics in Canada and internationally, turning tables in this context takes on different meanings. For instance, it could mean systematically assessing scientific cultures and communities to better understand how to attract and retain women in physics. Or, turning tables in physics could mean that the world would not have to wait another 57 years to see the next woman win a Nobel Prize in physics. Or, turning tables in physics could mean thoughtful incorporation of theories such as intersectionality [6] to increase all women's representation. As scientists, physicists, and human beings, how have we made space at our tables for women in science?

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The Illusion of Diversity on Citizen Science Platforms: Why Linguistic Representation and Translation Matter for STEM[1]

by Renée Desjardins and Danielle Pahud

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Summary

This essay submission examines linguistic representation on citizen science online platforms, with specific attention given to Zooniverse and the Canadian Citizen Science Portal.

The last decade has seen mobile technologies proliferate and the popularity of online participatory culture and online social media rise. In addition, crowdsourcing has become a default model for conducting large-scale projects in different contexts, including in academic research. The Search for ExtraTerrestrial Intelligence (SETI and SETI@home[2]) was a groundbreaking citizen science project and a well-known example of such a project within the citizen science and astronomy community. In many ways, opening research to the general public, particularly in online spaces, has led to a democratization of knowledge creation and dissemination, creating a sense that digital contexts are inherently more inclusive and diverse than traditional laboratories and classrooms. Indeed, the Tri-Agency statement on Equity, Diversity, and Inclusion (EDI) promotes increasing inclusivity in the research system[3]. While crowdsourcing research nominally meets this criterion, the implementation of projects and the degree to which these succeed in improving EDI, warrants nuanced reflection.

Early entrepreneurs of the social web-individuals like Facebook's Mark Zuckerberg or Reddit's Steve Huffman were optimistic that their platforms could remain neutral, and function without the gate-keeping mechanisms of 'traditional' media. However, many of these entrepreneurs had training in the areas of computer science or business. Few had formal training in disciplines in the social sciences and humanities (SSH), such as ethics, philosophy, or linguistics. Insights from these fields in the early days of social media, and arguably the early days of the Web, could have curtailed a number of issues we now face, such as: content moderation, technological surveillance, and techno-capitalism, which are often associated with contemporary social media giants. So, while the Web started as a 'uncolonized' space, over the years, intentionally or not, digital 'settlers' contributed to the moulding of this digital space. This has had an impact on access, accessibility, diversity, inclusion, and equity [1-3].

Our work is primarily concerned with investigating how scientific knowledge circulates in online digital spaces, using Translation Studies (TS) as one of our theoretical and methodological lenses. We contend that the web and most contemporary social media are inherently Anglocentric, which in turn has had some deleterious effects with regard to plurivocality [4] in the broadest sense. Bowker and Ciro [5] state that "English has emerged as the international language of scholarly communication–particularly in the domains of science and technology, despite the fact that only roughly 6% of the world's population speaks English as a native language." English is the language of the Internet and the *lingua franca* of the Web [6]. In TS, investigation of the asymmetrical 'flow' of knowledge creation and dissemination and the social and cultural implications this has is not an uncommon research strand; however, this body of research is seldom mobilized or even considered in the STEM fields. Succinctly: translation flow analyses (*i.e.,* the direction in which translated content/knowledge circulates) in our case studies point to the asymmetrical exchange of scientific knowledge and cultural capitals. Related research reveals that a proficiency in English generally facilitates increased access to scientific literature and a wider range of analytical, as well as technological, tools (*e.g.*, textbooks, software, apps) [7-10]. Our work started from a concerted interest in addressing what we considered disciplinary and epistemological silos between STEM and the SSH. More specifically, in our

1. This research is supported in part by funding from the Social Sciences and Humanities Research Council of of Canada.
2. https://setiathome.berkeley.edu/.
3. https://www.nserc-crsng.gc.ca/NSERC-CRSNG/EDI-EDI/index_eng.asp.

SSHRC[4]-funded research, we sought to examine a particular instance of where social media, crowdsourcing, STEM, and linguistic (in)justice intersect: online citizen science. In doing so, we hope to inform best practices in online citizen science project development and deployment.

Citizen science is defined as "a form of research collaboration involving members of the public in scientific research problems to address real-world problems" [11]. Fundamentally, citizen science is premised upon all lay citizens being able to contribute meaningfully to the scientific process. As technology has evolved, many of the STEM disciplines have turned to the general public's interest in and willingness to participate in larger-scale scientific projects. In the research that our team collected and reviewed, it appeared that English citizen science literature implicitly assumed English proficiency among online users, failing to problematize this assumption explicitly: let us recall that only 6% of the world's population reports English to be their native language. Said differently, for 94% of the world's population, any interaction requiring English means varying levels of (self-, automated, and/or external) translation and interpretation. While digital and mobile technologies can help dismantle hierarchies and remove barriers to access, thus amplifying marginalized voices within citizen science work in STEM, we noted that explicit strategies to foster increased *linguistic* diversity related to citizen science initiatives remain limited. In short: if citizen science projects are conceptualized, programmed, and deployed using only English, does this truly mean all laypeople can contribute equally? And if not, what do we stand to lose from epistemological, empirical, and qualitative perspectives?

To address these questions, we focused our analysis on two citizen science social platforms (for more on how citizen science platforms are considered social and participatory media, see [10]): Zooniverse and Canada's Citizen Science Portal. We selected Zooniverse as it is ostensibly the most popular[5] citizen science platform, hosting both SSH and STEM projects, and Canada's Citizen Science Portal afforded readily accessible Canadian content. By examining more than one platform, we were also able to conduct comparative analyses.

We monitored Zooniverse on a monthly-basis over a two-year period (May 2018-July 2020), tracking active, paused, and finished citizen science projects across the disciplinary spectrum (Zooniverse hosts both STEM and SSH projects) and analyzing, when applicable, translation flows. We established a list of criteria that would help us identify translated projects and multilingual project features, including multilingual menus/buttons/tabs, embedded machine translation features, bilingual or multilingual prompts, research team profiles *(e.g.,* bilingual or multilingual project coordinators), external social accounts on platforms like Facebook or Twitter that published in more than one language, etc. Our research assistants, Racky Diallo (Université de Saint-Boniface) and Neil Doerksen (University of Manitoba) compiled preliminary data and used Python[6] to generate data visualizations. Our initial hypothesis was that inherent Anglocentrism underpinned Zooniverse despite some of the efforts it claimed to have put in place to promote linguistic diversity. While project builder templates enable translation, our data shows that only a limited number of projects were available multilingually over the two-year study period. Moreover, we noted that in a majority of cases, English was the point-of-entry language and default project ecosystem language throughout Zooniverse. However, data from 2020 (January to July) suggests that linguistic diversity and translated projects are on the rise: in January 2020, 3.8% (9/232) of Zooniverse's project catalog was available multilingually or had translation features. In July 2020, this percentage increased to 8.9% (24/269). Our data also showed that the number of languages into which projects were translated (which ranged between 10-15 different languages on a monthly basis throughout 2018-2020) tended to be languages from the Global North, including Spanish, French, Dutch, and Portuguese among others; *i.e.,* languages considered to be central (see [12] for terminology related to the positioning of languages according to a gravitational model). That said, our analyses indicate that July 2020 had an uptick in language diversity, with Kannada being one example of a language outside the Global North. Our Zooniverse analysis did not indicate the use of or translation into/out of any Indigenous languages from North America. This is worth pause: when we consider that some of the land on which citizen science projects are conducted and the histories some projects invoke, this lack of linguistic representation has symbolic importance, and, in some cases real-world effects.

One of the major differences between the projects that appear on Canada's Citizen Science Portal, in comparison with Zooniverse, is that a relative degree of translation is often a mandatory project and platform feature — mandatory from the standpoint of research funding, but also from the standpoint of public sector communication in Canada.[7] This means that at a minimum, all active project descriptions (28 as of July 2020) on the portal main page are available in the country's two official languages (English; French), even if some of the project ecosystems are in fact unilingual. This would indicate that an official language policy and an emphasis on translation/multilingual features does influence linguistic diversity in knowledge creation and dissemination, particularly compared to sites like Zooniverse that do not have such explicit policies in place. It is worth noting that it would be difficult to enforce a language policy given Zooniverse is a transnational platform, though amendments to community guidelines that more explicitly address linguistic

4. SSHRC refers to the Social Sciences and Humanities Research Council of Canada.
5 "The Zooniverse is the world's largest and most popular platform for people-powered research." https://www.zooniverse.org/about.
6. Python version 3.6. https://www.python.org/downloads/release/python-360/.
7. For more on Canada's Official Languages Act: https://laws-lois.justice.gc.ca/eng/acts/o-3.01/.

diversity and justice could be envisioned. As with Zooniverse, we note an absence of Indigenous language representation on the entirety of the Portal catalogue at the time of writing. Given Canada's commitment to reconciliation and the fact that these projects are carried out in traditional Indigenous territories, Indigenous language representation is essential in Canadian citizen science. This would likely encourage the inclusion of Indigenous epistemologies, frameworks, and methodologies and promote language revitalization[8]. In this vein, we do not wish to speak in place of Indigenous scientists, citizen scientists and researchers, but we align ourselves with Indigenous scholars who have made the call for decolonizing and Indigenizing education and academic research (see [13]) and suggest the relative absence of these languages should be further scrutinized. For instance, we may ask whether barriers to representation lay within backend programming (an argument Instagram used when it addressed the late programming of right-to-left languages, for example), or a lack of outreach and relational connections with specific communities.

The scope of this submission does not allow us to provide in-depth analysis of each aspect of our two-year project. However, we feel it is worth sharing with the physics, citizen science, and larger STEM communities that there is epistemological value in considering translation, multilingualism, and linguistic representation in the *conception*[9] and deployment of citizen science initiatives. Our work answers the call made within the citizen science community for implementing practices that promote and sustain EDI (see [14]). Our work shows that the discourse on the supposedly democratic nature of online citizen science rarely addresses the fact that to participate, however minimally, one must first have *access* to technology and possess baseline digital literacy (to say nothing of other relevant literacies). The lack of critical reflection in relation to the digital divide in citizen science is problematic and further exacerbated when we factor issues related to linguistic representation and justice. The fact that not all citizens can contribute equally to citizen science initiatives further enforces hierarchies in scientific inquiry, promoting exclusionary rather than inclusionary frameworks. We argue that if citizen science platforms start from a more humanistic approach, rather than focusing primarily on automation, expediency and scalability of scientific discovery, in addition to low-cost labour (it is worth recalling citizens are not necessarily financially or symbolically remunerated for their contributions), then citizen science platforms would likely engage individuals beyond traditional epistemologies, beyond dominant language hierarchies, and would address more issues related to digital access.

8. Given that our team comprises non-Indigenous members, we do not feel it is our place to suggest which Indigenous languages should be included or how Indigenous representation might be best conducted on these platforms. We can work in a collaborative fashion to suggest some of the translation tools and strategies that can be deployed to foster increased multilingualism, however, and hope such collaborative initiatives will take place in the future. Ultimately, our project's data point to a gap and a lack of representation, and our hope is that Indigenous consultation and input would be a necessary next step.

9. The emphasis on conception is to underscore the fact that translation and multilingualism are at times thought of in the latter stages of a project or simply to meet funding criteria. In the latter case, translation then becomes a sort of 'graft' instead of an integral part of the project's conceptualization from start to finish. Without citing every issue this causes, it can mean hastily produced translations or unwarranted recourse to machine translation (which can pose other challenges inherent to algorithms and training data).

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THE HIDDEN PRIVILEGE

BY EMILY ZHANG

Being a visible minority in physics comes with its challenges given the field's longstanding history of discrimination against women, nonbinary folk, and people of colour. These experiences are often compounded for those who are members of more than one of these groups. Although there are important efforts to increase representation, they often forget to address the hidden axis of privilege: wealth. Unlike gender and race, one's socioeconomic status is harder to presume at first glance. In this testimonial, I will use my own journey into a PhD to illustrate how the intersection of my gender, race, and social class has resulted in unique modes of inequity during my physics career.

Growing up, I never internalized the fact that I was underprivileged. My parents are first generation Chinese immigrants who did not speak English, so they struggled to provide for most of my life. My childhood was spent under the poverty line, and I went to school in a low-income, highly culturally diverse area. Not only were my parents constantly worrying about food and shelter, they were also poorly equipped to navigate the existing social and institutional structures in place to stimulate my interests in science. Nevertheless, my circumstances were comparatively better than many of my peers, some of whom were not in a place to even consider higher education — the act of which is in itself a privilege.

Being unaware of the opportunities that a degree in physics presented, I rationalized that my only choice was a mainstream career path to secure income, such as medicine or pharmacy. I spent two years in biopharmaceutical sciences before realizing that my passion for physics was worth pursuing. Faced with uncertainty, I took a leap of faith and switched programs, and the abrupt shift in demographic among my peers became immediately apparent. Not only was I one of the few women, but I was also one of the few people of colour — a drastic difference from my upbringing in a multicultural space. It was also the first time my comparatively low socioeconomic background was made apparent to me. I was not equipped with the cultural capital to navigate predominantly male, affluent, and privileged spaces. There was an incongruity between my social identity and my identity as a physicist. I felt alone.

During my studies, I worked full-time, which not only allowed me to finance my own schooling, but also to assist my parents with their debts and expenses. Becoming financially stable enabled me to create opportunities for myself, something which was not afforded to me growing up. Even so, my decision to work while studying full-time was met with confusion from my peers and professors, as physics was not the sole target of my efforts. The ability to focus purely on academic studies — a privilege held by most of my peers — was something I worked hard to obtain.

As I enter into the second year of my PhD in a newfound position of economic privilege, I can finally fully focus on my studies. Although there are fewer financial obstacles, many social and cultural barriers are still prevalent. Women of colour tend to be taken less seriously already [1,2], but this effect is amplified when people learn of my choice to work and undertake EDI activism in place of extra physics courses, despite my academic record and research experience. I feel a constant need to prove myself, reaffirmed by remarks about my unpreparedness, or implications that my accolades are due to my identity rather than my scientific abilities. These small but constant microaggressions have built up in me over time, proving more harmful than absurd racist and sexist remarks that can be easily dismissed.

I share my experiences in hopes of lessening the isolation felt by the minority of people who can relate to my hardships. Physics institutions are gradually moving toward a more diverse and equitable environment, but there is much work to be done. We need to inform future outreach to take a more longitudinal and holistic approach - one that accounts for gender, race, *and* socioeconomic background. Before programs that address equity, diversity, and inclusion can begin to take effect on an intended individual, the identity of the individual must be commensurate with that of a physicist, and that requires a fundamental demographical and cultural shift in our community. I encourage those who hold positions of privilege to be open-minded, and those who identify with my story to share their own experiences, as our perspectives are crucial for creating understanding and a more inclusive environment in physics.

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LGBTQ+ IDENTITIES IN STEM: A STEADY LEAK

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Innovation and creativity in science, technology, engineering, and mathematics (STEM) are best fostered through a diverse researcher population [1]. However, lesbian, gay, bisexual, transgender, queer, and other sexuality and gender minority populations (LGBTQ+) have been underrepresented in these fields, undermining this goal [2]. Underrepresentation of these groups emerges in two streams: low numbers of STEM researchers who are comfortable openly identifying as members of the LGBTQ+ community (*i.e.,* being 'out') at their institutions; and a pervasive culture in STEM that discourages visibility, lowering retention of LGBTQ+ researchers in these fields.

The outflow of minorities from STEM has been modeled as a leaky pipeline [3], where individuals leave STEM at various stages of their careers. In this review we will focus on identifying obstacles to LBGTQ+ retention in STEM using the leaky pipeline model, concentrating on the undergraduate to late career stages of the pipeline.

Past research shows retention in STEM is strongly correlated with science identity — a personal sense of belonging in STEM [4]. Undergraduate research participation, which bridges the gap between the classroom and practical application, is correlated with strong science identity [4,5]. Curiously, while LGBTQ+ STEM students were found 8% more likely than their non-LGBTQ+ peers to be involved in undergraduate research, the same LGBTQ+ students were 10% less likely to stay in STEM, even when controlling for other factors known to support retention (*e.g.,* having parents/guardians in STEM) [4]. This is a sizeable loss of LGBTQ+ students from STEM, occurring at an even faster rate than for women [4]. The contrast between high involvement of LGBTQ+ students in undergraduate research and their poor retention raises several questions: If research participation is not retaining LGBTQ+ STEM students, what is preventing it? What extra challenges might drive LGBTQ+ people from STEM?

SUMMARY

The 'leaky pipeline' in science is notably leakier in minority groups. Among and intersecting with these groups are LGBTQ+ individuals; however, the reasons for the leak in this demographic, particularly retention after entry to undergraduate programs, and unique challenges LGBTQ+ scientists may face, bears further exploration and reflection.

It is generally assumed that STEM has comparable amounts of LGBTQ+ people to other fields; however, estimates suggest that STEM has 17-21% fewer LGBTQ+ people than expected by the general population [2]. Additionally, LGBTQ+ people in STEM are less likely to be *out* at their institutions than in their private lives compared to in non-STEM fields [4-7]. Lower overall visibility of LGBTQ+ STEM majors leads to feelings of isolation among those members remaining in STEM, discouraging their retention. Why are LGBTQ+ scientists not *out*? Studies of American LGBTQ+ physicists found that 30% were told not to come *out*, and 50% of transgender and non-binary scientists had experienced harassment in their departments [1,5,6]. When surveyed, LGBTQ+ faculty and students often cite the uncertainty of reception by colleagues and supervisors as strongly influencing their willingness to be *out*, with approximately 20% of LGBTQ+ people reporting feeling uncomfortable in their departments [1,2,8]. A commonly reported fear is that coming *out* will hurt, or cost them, their careers as many countries lack legal protections from job loss due to gender identity and sexuality [4,6,7]. This leaves individuals with the hard choice of being *out* and risking backlash or termination, or remaining hidden, which often leads to poor mental health [6]. This sense of isolation and discomfort experienced by LGBTQ+ people in STEM creates feelings of being unwelcome, prompting exits from the STEM stream.

A 2016 report by the American Physical Society [1] found 36% of LGBTQ+ respondents had seriously considered leaving STEM in 2015. Similarly, a UK study in 2019 [8] found 28% of LGBTQ+ respondents, rising to 50% in transgender and non-binary participants, had also considered leaving STEM; however, only 16% of non-LGBTQ+ participants had considered the same. Why? A highly cited reason is the atmosphere in STEM around discussing sexuality and gender identity [2,4-7]. The prevailing mindset in STEM is that LGBTQ+ identities are a personal topic, and unnecessary to discuss within STEM's ideally objective, merit-based environment [2,6,7]. This persists even within STEM's diversity programs: research chair competitions in Canada, as well as NSF and NIH competitions in the United States, do not include LGBTQ+ identities in their equity and diversity targets [2,9]. To perpetuate the notion that discussions and visibility of LGBTQ+ identities are unimportant in STEM, or within institutional diversity criteria, demonstrates an oversight of the challenges LGBTQ+ people can face and pushes many potential STEM majors out of the stream [1,2,4-8].

Networking with peers and colleagues often critically influences success in STEM [10-12]; however, the same networking opportunities are not always available to LGBTQ+ people. Casual conversation rapidly becomes daunting for LGBTQ+ individuals to navigate when questions like "Do you have a husband/wife?" mean deciding whether or not to come *out*. As many peers and colleagues are from cultures less accepting of LGBTQ+ people, being *out* can strain or cost connections and collaboration opportunities. These challenges are often most pronounced for transgender and non-binary populations [2,8], where legal name changes mean coming *out* repeatedly to claim any publications that exist under their previous name, or abandoning their claim to those works. In STEM's global community these difficulties are greatly hindering, as many institutions are located in regions where it is unsafe or illegal to be LGBTQ+.

Adding to the challenges LGBTQ+ people face being *out* in their professional lives, personal issues can also greatly impact their success. Notably, many young LGBTQ+ people face rejection and abandonment by their families [2]. Moreover, LGBTQ+ people are at higher risk for homelessness or poverty with LGBTQ+ youth being five times more likely to be homeless than the general population [13]. The strain of fiscal instability, as well as emotional distress and mental health effects of rejection, can make continuing professionally unfeasible. This ultimately contributes to LGBTQ+ people having to leave STEM due to purely socioeconomic factors.

We have reviewed several factors discouraging LBGTQ+ scientists from coming *out* publically in their institutions, particularly in education and early career, and how this contributes to the leaky pipeline. These factors ultimately impact LGBTQ+ visibility in STEM, causing subsequent leaks as careers progress to more senior positions. Many academics report being unable to identify any colleagues who are publicly *out* as LGBTQ+ and academics, more than non-academics ($p < 0.0001$), were found less likely to know if any LGBTQ+ supports exist at their institutions [6]. This unawareness is even more pronounced in undergraduates, many of whom cite never knowing of any LGBTQ+ scientists [2], which contributes to feelings of seclusion that can drive them out of the STEM stream. Put simply, LGBTQ+ researchers will not be well retained in STEM when they cannot see themselves in it.

Out LGBTQ+ faculty know this best, as several have reported receiving visits from LGBTQ+ students outside their disciplines under the guise of having vaguely related questions to their field, hoping to find confirmation of LGBTQ+ scientists [2]. Faculty more prominent in advocacy have gotten emails from students at other institutions looking for advice on how to exist as an LGBTQ+ person in STEM [10]. This demonstrates a clear need to close the gap between perceived and true numbers of LGBTQ+ scientists to retain these students in STEM. As described earlier, strong science identity is important to retention; when upcoming researchers cannot see themselves, it will be difficult for such an identity to form. Improving on this for young LGBTQ+ STEM majors requires creating and fostering work and study environments where academics feel comfortable coming *out*.

In addition to invisibility and isolation, LGBTQ+ STEM majors have reported higher rates of discrimination and harassment than their non-LGBTQ+ counterparts [1,8]. Unsurprisingly, such harassment is a potent driving force for leaving STEM and undoubtedly contributes to the low retention of LGBTQ+ populations. Harassment rates are even higher among subpopulations of the LGBTQ+ community, with non-binary and transgender people being approximately twice as likely to experience harassment in their workplace than LGB people, and these risks are higher still for LGBTQ+ people of colour [1,7,11]. For many LGBTQ+ STEM students and staff, concerns of harassment factor heavily into their choice to not be *out* [1,2,6,7,11]. This is a self-feeding effect: low visibility leads to leaking LGBTQ+ populace from the STEM stream, however those who are *out* become bigger targets of harassment, and so themselves "leak out", leading to a net reduction of LGBTQ+ individuals in STEM. Given the previously discussed low retention of LGBTQ+ students despite undergraduate research participation, it may well be that exposure to harassment events in early research dissuades them from continuing.

LGBTQ+ people are increasingly more visible in the population. Despite this, they have been poorly retained within STEM due to: low visibility, isolation, fear, harassment, and the prevalent mindset that such identities are too personal for open discussion in STEM. This can be improved upon, and efforts have been made by various advocacy groups (*e.g.,* 500 Queer Scientists, Pride in STEM, etc.) to facilitate spaces for LGBTQ+ scientists to connect and encourage more scientists to be *out*. However, there is still much room for improvement, particularly in increasing awareness of STEM's diversity to undergraduates and working to include conversations about identity in STEM at large. Improving visibility will reduce the leaks of LGBTQ+ people in the pipeline, which can only serve to increase STEM's diversity and foster greater innovation going forward.

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Counterspaces that Support Identity Work in Physics

by Allison J. Gonsalves and Hannah R. Chestnutt

Physics continues to lag behind the other sciences in the recruitment and retention of minoritized students like women, and particularly women of colour, to post-secondary degree programs (*e.g.*, [1]). Reports of 'chilly climates' for women [2], unsupportive classroom environments [3], and characterizations of these disciplines as masculine [4,5], have provided speculation as to why the gap persists. Sociocultural researchers have suggested that the development of a science-identity (*e.g.*, [6]) or specifically physics identity (*e.g.*, [7,8]) can influence persistence and success in physics. Researchers have also found that participation in STEM (Science, Technology, Engineering, Mathematics) national groups or campus groups can impact minoritized students' persistence in physics programs (*e.g.,* [9-13]). The focus of recent research has thus been on the link between science-identity formation and the resources students can access through equity, diversity, and inclusion (EDI) initiatives [12], specifically in physics [14].

EDI-focused STEM clubs and programs have been known to influence students positively by opening pathways into STEM fields. Socially and academically supportive networks are built when EDI STEM clubs/organizations allow minoritized students to feel more connected with a community of students with similar interests and experiences, and also more connected with the STEM community at large [9,10]. In particular, deficit notions of minoritized students can be challenged and a positive collegiate racial climate can be established within initiatives that serve as *counterspaces* (*e.g.*, [15]). Counterspaces are described by Ong and colleagues as safe social spaces that "offer support and enhance feelings of belonging in STEM" (p. 207). Solórzano et al. [15] suggests that in these spaces students may vent frustrations by sharing stories; validate their own experiences and learning; and counter deficit notions of minoritized students (especially women of colour). By definition, these 'safe spaces' "lie in the margins, outside of mainstream educational spaces, and are occupied by members of non-traditional groups" [12]. In their research, Ong and colleagues demonstrated that counterspaces offered opportunities for students to vent frustrations and form networks with other students, faculty, staff and other allies who shared students' experiences of microaggressions or discrimination.

Summary

This research essay discusses the potential that counterspaces—safe spaces for minoritized groups in physics—have to support students' persistence in physics. Focussing on undergraduate and graduate learning environments, we describe attributes of counterspaces in physics, and the positive identity resources (relational, ideational and material) students can access through them.

A Department as a Counterspace

In physics contexts, counterspaces can provide alternatives to the typical learning space in which there are often limited available identities, and efforts to create a sense of belonging for minoritized students (*e.g.*, [3]). A study by Johnson and colleagues [16] demonstrated that while counterspaces are often situated outside of formal academic spaces, departments themselves can be structured to act as counterspaces. Johnson and colleagues identified various features of a physics department shown to act as a counterspace for women of colour in physics. First, students reported that rather than isolation (a common experience for minoritized students in physics), they found friendship and support in the department. This was significant for students, especially women of colour, who often find themselves feeling alone in departments that are predominately populated by men. Minoritized students also reported that they trusted that their professors would deal with microaggressions so that they didn't have to. Microaggressions are so prevalent in physics cultures that they are thought to be a significant factor in attrition from graduate programs for women of colour (*e.g.*, [17]). Students trusted that their professors would address microaggressions in classes, or pull aggressors aside to confront their behaviour. This created a culture of safety in the classroom and facilitated a sense of belonging for minoritized students. Finally, Johnson and colleagues report that professors in this department went out of their way to create a sense of community among students — a strategy that is counter to the cultural expectations for physics departments that have historically been constructed as competitive and individualistic [5,18].

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A department as counterspace created opportunities for students to interact with each other and with professors outside of class time. Students were encouraged to present their own work frequently, and public spaces were provided for students to work together, in consultation with faculty members. Johnson and colleagues argue that for this department to be a counterspace, the departmental members "don't just leave it to chance that underrepresented students will get knit into this community" (p. 359).

A COUNTERSPACE EMBEDDED IN A DEPARTMENT

Our own research with an EDI group for faculty and students in a physics department suggests that counterspaces for students (and faculty) provide various resources that can facilitate students' positive identity work in physics. Our study (see [14]) investigated the resources made available through an EDI group (formerly known as a Women in Physics group) in a physics department at a large, research-intensive university. This EDI group is chaired by a faculty member from the department, and is provided with financial resources to fund teaching assistants who run various aspects of the group (outreach and communications/event planning). The group was established as a working committee to address issues of harassment, microaggressions, isolation and imposter syndrome (*e.g.*, [19]) that students experienced in the department. However, our research suggests that although this group was established as a departmental working group, for the students participating in it, it operated as a counterspace. This is a positive example of a counterspace that can become embedded in the departmental structure of a physics unit in ways that provide *relational*, *ideational,* and *material* resources [20] to students. Our analysis suggests that the counterspace provides relational resources in the form of access to faculty members outside of class and laboratory time. The counterspace acted to flatten the prevailing hierarchical structure in the department, and provided opportunities for faculty, students and staff to interact informally in new ways. Social activities provided students with new opportunities to relate to faculty, and to approach them with issues related to being a minoritized student in a department with predominantly male students and faculty. These new relationships brokered ideational resources for minoritized students. Whereas celebrated physicist identities tend to be associated with traits like competitiveness, brilliance, and solitary social behaviour [9,21], students reported being able to see themselves as physicists who are also empathetic community builders. Thus, the EDI group broadened the kinds of physicist identities that were available to minoritized students and others in the physics department, and also what kind of identities were valued by its members. The counterspace also provided material resources to students in that teaching assistantships were funded to allow students to do the important work of organizing inreach and outreach that supported others. Funding for the EDI group was provided by the department and was critical for its functioning. Workload credit was also granted to faculty members who played organizing roles within the group.

CONCLUSION

To be successful, institutionally-led counterspaces require the allocation of both human and financial resources. Both of these types of resources are needed for the creation of forms of engagement that support students and their relationships with faculty and with one another. Critical to the success of both of the counterspaces described in this short paper were the commitments that institutions made to ensuring that faculty and staff responded to students in ways that validated their experiences. Faculty and staff were resourced in ways that promoted their own abilities to deflect episodes of microaggressions away from minoritized students, and to combat isolation by ensuring that minoritized students had opportunities to engage with each other and opportunities to access supportive faculty members outside of class time. It is important to note that the success of these programs cannot rest on a single faculty member or administrator. Our analysis [14] suggested that EDI groups like the WPG could be fragile in structure, if tasks and leadership roles are not distributed across several faculty members and staff. The removal of key faculty members or administrators from leadership positions within the EDI group could lead to a vacuum of information and support. Thus, the responsibility to initiate and maintain a successful EDI counterspace requires commitment from many members of the physics department. This can be enabled by allocating financial resources (as in paid student leadership positions, workload credit for faculty members, and workload allocation for staff members) to the operations of the group. It should also entail rotating leadership roles to ensure that responsibilities are distributed, and structural holes are not formed when members leave (graduation, sabbatical, etc.). While counterspaces tend to exist on the margins of mainstream educational spaces, the two examples described here demonstrate how it is possible to establish these spaces within the structure of the traditional physics department. The benefits to students are numerous, but most notably, it can create an opportunity for minoritized students to feel safe in often hostile physics learning environments, and to begin to imagine physics futures for themselves.

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BEST PRACTICES FOR ORGANIZING AN INCLUSIVE EVENT OR CONFERENCE

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BEST PRACTICES FOR ORGANIZING AN INCLUSIVE EVENT OR CONFERENCE

Planning for Inclusivity

- Consider diversity needs from the start of event planning, not as an afterthought
- Diversity includes racial, ethnic, gender and sexual identity, religion, physical ability, career stage, socio-economic status, caregiver responsibility, regional location, etc.
- Create a diverse organizing committee and arrange for inclusivity training for the whole team
- Designate a team member to oversee all Equity, Diversity and Inclusion (EDI) aspects and another to receive and process accessibility and accommodation requests

Participation

- Aim for diversity across all participatory roles, such as
  - Organizing committee, staff, volunteers
  - Keynote, invited and contributed speakers, poster presenters
  - Panel members, session chairs, performers, emcees
- Offer registration fee, transportation or housing subsidy for financially disadvantaged attendees
- Consider live streaming and recording the sessions for remote participants

Program Development

- Ensure the agenda has regular health breaks
- Incorporate workshops, social activities and networking events to mix up the format
- Consider an interactive EDI workshop but recognize that it will only attract a fraction of the attendees, especially if it is in parallel with other sessions
- Schedule an EDI talk during the highest profile plenary session to ensure the largest audience
- Give speakers and poster presenters clear guidelines for preparing accessible visuals

Code of Conduct

- Develop an EDI statement, a code of conduct and an anti-harassment policy and plan
- Highlight the statement, code and policy on the website and in the printed program
- Provide a system to report conduct concerns, *e.g.,* anonymous online form or staff with distinctive badges
- Give session chairs guidance on how to conduct the sessions in an inclusive manner, *e.g.,* select a woman for the first question, shut down inappropriate comments

Website and Registration

- Follow accessibility guidelines for the website, the advertising and any printed materials
- Require agreement of the code of conduct in the registration process
- Provide gender-inclusive options for preferred pronouns, *e.g.,* Mx, or include a blank field
- Include option for private (as opposed to shared) hotel room (do not ask for any justification)
- Include a free-form field for special accommodations requests and follow up with requestor
- If clothing will be provided as swag, include a field for requested size and fit, *e.g.,* loose
- Include a section on self-identification to help with reporting and post-event evaluation

EDI Accommodations

- Childcare needs
- Private space for breastfeeding, prayer, counselling, etc.
- Facilities for service/therapy animals
- ASL interpretation or Real Time Captioning, note-taking, reserved seating, assistive device rental
- Dietary restrictions and allergies; scent-free environment

BEST PRACTICES FOR ORGANIZING AN INCLUSIVE EVENT OR CONFERENCE Plannin

Choice of Venue

- Safe location, with good exterior lighting and transit connections, and a variety of housing options
- Wheelchair-accessible stage, rooms, hallways, bathrooms, elevators, parking and drop-off area
- Gender-inclusive bathrooms. If none, designate one as such with signage and advertise it
- Sound system to accommodate hearing impairments
- Quiet, effective and adjustable temperature/humidity control

Catering

- Label foods by ingredients to accommodate dietary restrictions and allergies
- Offer self-service water and caffeine-free beverages, labelled accordingly
- To keep things simple, consider offering a fully vegetarian menu, with some vegan and gluten-free options
- Many folks consider environmental impact before attending an event; incorporate eco-friendly practices, such as avoiding straws and using a waste-free caterer; most hotels offer this option for a modest fee

Social Events

- Mix up the schedule for social/networking events so they are not all at the end of the day
- If you decide to offer alcohol at a social event, make sure
  - that non-drinkers feel welcome and have access to a variety of delicious non-alcoholic drinks
  - that everyone feels safe; have a plan to deal with intoxicated guests
  - to limit the amount of (free) alcohol available via tokens or tickets (no open bars!)
  - to provide some food and unlimited water in self-serve containers

Event Welcome

- Use non-gendered language, *e.g.,* "Welcome everyone" instead of "Welcome ladies and gentlemen"
- Include a land acknowledgement, as appropriate, and an inclusive environment statement
- Mention locations of washrooms, accessible entrances, emergency exits, services, special food requests, conduct concern reporting system, etc.
- Emphasize the importance of using microphones and staying on schedule
- Encourage attendees to fill out anonymous post-event evaluation forma

Evaluate Success

- Post the evaluation form on the website and send the link by email to all participants
- Inquire about catering, handling of accommodation requests, services provided, etc.
- Provide a free-form field to solicit general feedback
- Ask for suggestions for potential improvements and make note for your next event
- Consider criticism (constructive or otherwise); respond with kindness and an apology, if merited
- Review registration statistics and compare to your original diversity goals

Additional Resources

- https://inclusionlens.yorku.ca/
- https://www.canada.ca/en/employment-social-development/programs/disability/arc/inclusive-meetings.html
- https://geekfeminism.wikia.org/wiki/Conference_anti-harassment/Policy
- https://reachwater.org.uk/resource/best-practice-guide-developing-inclusive-conferences/
- https://www.socialtables.com/blog/event-planning/accessibility-guidelines/
- https://medium.com/@mxsash/how-to-build-a-better-alcohol-culture-at-your-tech-conferences and-events-9e1cce7179c0

BEST PRACTICES FOR ORGANIZING AN INCLUSIVE EVENT OR CONFERENCE

EQUITY, DIVERSITY, AND INCLUSION: CONVERSATIONS AT TRIUMF

BY ANONYMOUS TRIUMF STAFF, EDITED BY CARLA RODRIGO

TRIUMF is an institution with over 50 years of history in accelerating discovery. While we have made great leaps in science; we are not immune to the systemic issues that disproportionately affect the lives of underrepresented groups in the scientific community. In recent years, we've worked to overcome the gaps in equity: we've established the Equity, Diversity, and Inclusion Committee, we've implemented unconscious bias training, and we've reached out to the broader community in hopes of inspiring a diverse generation of innovators. But there is always more work to be done, and there should always be more room at the table for those who have not been given a seat. The following collection of personal statements from members of the TRIUMF community, anonymized out of respect for privacy, aims to document the steps taken thus far, and the leaps that remain still ahead of us.

ACCOMMODATING FAMILIES

"I joined TRIUMF as a postdoc in 2015 and it hasn't been easy since the beginning, in terms of making jobs and kids compatible. Families with young kids are part of the invisible minorities at TRIUMF. When I moved here with my wife, who is also a PhD, the first frustration was the waiting lists for daycare. The waiting period can vary from 1-2 years, which is a huge problem. In addition, TRIUMF lost the priority that other UBC staff have in the UBC daycare services, and other Vancouver daycares are too expensive for postdoc salaries. Every two years, postdocs are new again, which means that problems can repeat every two or three years. Now, COVID has brought us many changes in family managing. Without schools running, and with a toddler still on the waiting list for a daycare spot, it is extremely difficult. But there have been improvements, and I think the Graduate Students and Postdocs Society (GAPS) at TRIUMF has helped to report and address important issues. It's a very good committee that should be supported — they help people avoid social isolation by interacting with the community.

Carla Rodrigo <crodrigo@triumf.ca>, Community Engagement Specialist, 4004 Wesbrook Mall, Vancouver, British Columbia V6T 2A3

SUMMARY

This collection of personal statements on EDI from the TRIUMF community serves to acknowledge and amplify the lived experiences of underrepresented groups at the lab.

In terms of diversity, as an international facility, sometimes people arrive at TRIUMF as non-native English speakers, myself included. Foreign language speakers are welcomed, but communication can be hard if the audience does not have enough empathy. The level of English fluency can vary due to different reasons, such as the public/private education differences in non-English speaking countries. My communication skills have improved a lot during these five years, but I remember how difficult it was to follow some meetings at the beginning, when slang was present in conversations. In addition, in terms of diversity — at TRIUMF, some places of origin are overrepresented compared to other regions of the world. This is partially understandable because some countries have a longer tradition of nuclear research, however, I would expect to have more representation from the countries and cultures that make up the population of Vancouver. And I'm not talking only about senior scientists; looking at PhD students, I would expect that TRIUMF should be representative of the diverse community living in Vancouver.

Regarding gender, I think TRIUMF has been really good compared to others, and while I agree that we should have more women in physics, just having more women doesn't capture everything. We should also have a look at their backgrounds, both women and men. Some may come from a family with enough opportunities that university was no problem; other students may be coming from very low-income families. In that situation, are we really evaluating the same effort? Are we taking this class difference into account when discussing diversity?"

INVALUABLE MENTORSHIP

"There's something to be said about representation, right? I had a particular affinity for my grade 11 physics teacher — not only did she teach us physics, she taught us a general approach to solving problems in science. The main factor that enabled me to stick with this career path and succeed was the string of mentors I was lucky to find, starting with her. Every one of them left me convinced that they would back me on just about anything. They made it clear that they genuinely wanted me to succeed. I didn't have a close personal relationship with all my mentors, but if I needed anything and I could make a solid case for it, I would get their support to make it happen.

There's a bit of an exhaustion factor when having these discussions about EDI issues over and over with a bunch of different people. Because we are all scientists, I keep a few scientific papers and studies handy to say, "well, actually…", but it depends on the person I'm interacting with. I usually spend more time trying to convince people who are closer to my peer group; it's more comfortable to do so. As I become more established in my career, I hope to turn around and find more time and energy to be active with community efforts, but I think we need to be respectful of people's time when it comes to these issues. It's good that people from underrepresented groups are given a voice, but they shouldn't feel pressured into it — they should feel like they are in a position where they can say no to things. It's important to have mentors who can tell them, "You don't have to say yes to everything."

There are so many awesome students running around TRIUMF, and I hope they feel the way I felt about my mentors when they receive support from me. When I see applications that don't look like the rest of the pile, I make a conscious effort to make sure I'm not dismissing them as a reflex. I always take a second look and ask, "is that actually disqualifying, or is it just different?". There's the oft-repeated trope that in a purely merit-based system the cream will rise to the top. First, that isn't entirely true, and in a perverse way it absolves people from working on their unconscious biases. The general requirements for people in hiring positions to do unconscious bias training is good, but I wish there was broader encouragement for everyone to do it, even those hiring summer students. It doesn't take long, and it can make someone's career when you give them that first job. I don't think we can rely on the generational shift that people sometimes think will be enough; these big, bulky systems are impossible to change from the inside without a conscious effort."

UNDERSTANDING DIFFERENCES

"When I first got to TRIUMF, the environment was very different — most of the guys in the machine shop were a lot older, and they had similar backgrounds. I'm of East Indian descent, and when I first arrived, I felt welcomed by some of the guys and not so much by others. There were racist comments which was nothing new to hear. Sometimes I even nodded my head in agreement as a survival mechanism. In our shop, there was another man of East Indian descent who was picked on regularly, and even though I was of the same race their comments weren't directed to me. They even tried to include me or get my approval of their racist comments. I think this was because I was quite young, impressionable, and looking to fit in. This man who was discriminated against stood up for himself, and I didn't. I grew up in a neighbourhood that was fairly racist, and even in school I would laugh with everyone so that I wouldn't be singled out. It was a matter of safety at the time, safety and belonging. Back then I didn't have the leadership qualities that I do now.

Personally, I made close relationships with the people I was working with, and the racist remarks just seemed to stop — if there were comments made, it would be followed by "Oh, sorry, I was just joking". I think it was because I tried to fit in and see their point of view. By the time I left the shop, I had good friendships and we could transcend the race issues. Now, more than ever before, I'm sharing my culture with others. The more I looked to spirituality, the more I found certain practices from my culture that made sense and were backed by science. My parents practiced Hinduism in our home, so it must have had an influence. I have a passion to share the gifts of my culture because of those moments of discrimination.

Amongst our group here at TRIUMF, we openly talk about our differences and we can even joke about them. Recently, our group dynamic has changed after hiring some young women from different backgrounds. It's a more colourful, more vibrant environment as they share their culture with the rest of the group. This decision to hire them totally changed the energy of a group — it's like adding oil into a machine. Now, when facing others who can't see beyond race, I try to understand what's causing their fear. The baseline of any resistance and resentment is fear of the unknown. If I can understand that fear, I can help put them at ease. And if they want to, they can change; if not, that's their choice too. Don't be ashamed of who you are, because it's not you, it's them."

INSPIRING SUPERVISORS

"Like many other women, I ended up here totally by accident. When I was in high school, I didn't like physics or math at all; I thought I was really bad at it, which I think is another common experience among women. I don't remember having any math or science teachers that really inspired me, but it's also very dependent on how much exposure you've had to different ways of thinking about the subject. Math was very much: "learn this formula, plug in the numbers, memorize this". As soon as I got to university, it was a complete flip. You didn't need to memorize; you needed to understand how it worked. For me, that was super important. One of the things that we can do differently when talking to kids is showing them there are other ways to think about things. I used to do outreach, and when kids drew a scientist, they would all draw Albert Einstein. It was important to ask, "Why do you think all scientists are old, white men?" If that's stuck in your brain when you're six, that becomes a bias that's hard to overcome.

Amongst my peers, it was not uncommon for somebody to say, "Are you sure you didn't get this job because you're a woman?". The first time I heard it, it freaked me out and I thought, "Maybe this is true". I asked my boss if I was a just a diversity hire and he said no, of course not. A friend of mine was surprised to hear that every woman in physics I know has been told they were just a diversity hire; that's a very normal thing to have heard multiple times in your life. There are tons of similar things that people of colour in science have heard or experienced that I can't imagine. But it's good to hear about these things now and know that they exist — that's how you move forward.

After student life there were definitely moments when I was taken by surprise, but I feel like I've had a pretty good experience in the physics world. At TRIUMF I feel included all the time. The people in our group are so inclusive that I always really feel like a part of a tight-knit team. What's really important is knowing that your supervisor has your back. There were so many times when I could have dropped out of physics, but part of the reason I stayed was because I really respected my supervisors. Mentorship is key — we don't really spend a lot of time training people how to do that, and I think that's a big failing on our part. We should help physicists develop the skills to be a mentor for someone else."

MAINTAINING DIVERSITY

"I was more of an artistic person, not a science person, but because I belong to an Asian background, my mom believed that my profession should be in the sciences. Also, I always got high scores in science, and with the passage of time, I started liking it. For me it was like a magic wand in your hand for turning the impossible into the possible. I've always felt like I belong in STEM, but what discourages women is losing opportunities for promotions. I have all the skills and the experience, but I know that when an opportunity for promotion comes, my chances are lower. Some women spend years of their lives working in labs as technicians, postdocs, or even research scientists, but have not been able to reach the level of professor. It can be discouraging when you see a man who has the same skills and experience, but he is given more opportunities.

On the subject of EDI, we always say equity, diversity, and inclusion, but I think it should be first diversity, then equity, then inclusion. You must first have a diverse environment in your institution. In a diverse environment there will be more open minds and open hearts — and that's what you need in science and in international collaborations. We come from different backgrounds; you will have your own perspective and frame of mind, and I will have my own. When we communicate with each other, we can become more equal.

Equity comes next — for me this means balance, not only between different cultures and backgrounds, but also between different genders. Do people in the same position have the same salary level? Often men have better benefits, higher salaries and more chances of being promoted than women. At TRIUMF, we don't see many women in top management, but this is gradually changing for the better.

Last is inclusion. I think inclusion will come automatically when you create an environment with equality for all, where everyone's opinion is heard, and people offer their opinions in a respectful, ethical way. It's not about winning or losing, it's about a discussion. Many institutions have diversity, but the real task is to maintain it. It's important that we try to retain people who are enthusiastic and productive, ensuring they feel comfortable. Even if there is one such person in the institution, they will inspire others. Don't lose passionate people. Don't let them be silent. One candle can light a thousand."

The Only Social Psychologist in the Room

by Eden Hennessey

Recently, I was (to my knowledge) the only social scientist in the virtual room with 500+ physicists across Canada. My goal was to present the audience with research and recommendations for anti-racist practice as a part of #ShutDownSTEM; a call for academics to learn about anti-black racism. This experience demonstrated the value in social and natural scientists engaging with each other in discussions about equity, diversity and inclusion (EDI). Illustrating this notion, in this testimonial I will reconstruct my cognitive process as I prepared, delivered, and reflected on the talk, connecting my thoughts to established effects in social psychology.

As a confident presenter, it still occurred to me that I might not be taken seriously — for several reasons all documented by social science. First, this thought could have arisen due to *stereotype threat*, whereby people's performance suffers because they fear that they will confirm a negative group stereotype (*e.g.,* "Women are bad at math"; [1]). Second, I'm acutely aware of cross-cultural stereotypes associating men with science and women with arts [2]. Third, I am cognizant that women tend to be perceived as more warm than competent, in contrast to an audience of physicists, who are stereotypically perceived as more competent than warm [3]. A fourth possibility is a phenomenon common among social scientists: researchers have coined the term *physics envy* [4], to refer to a propensity for social scientists to see their work as less scientific than those in natural sciences.

Summary

As a Social Psychologist, I recently joined 500+ Physicists united in an academic strike (#ShutDownSTEM) to discuss anti-Black racism, equity, diversity, and inclusion. Using autoethnography, I describe this unique experience, noting how questions and requests for resources indicate readiness to learn about wise practices and engage in self-reflection in Physics.

I started the talk with two questions: "What is racist?" and "What is anti-racist?", which might seem simple to a highly educated audience. However, to assume all attendees understand and are committed to anti-racism, may be engaging in the *false consensus effect*; a tendency to overestimate how much other people agree with your beliefs, attitudes and values [5]. So, I asked the questions, and crafted the talk around a report aptly titled 'The Time is Now: Systemic Changes to Increase the Representation of African Americans in Physics' [6].

Delivering the talk, I thought it was going well; attendees were engaged, asked questions, and generated ideas to make physics more inclusive. As excited as I was, it occurred to me to temper my optimism; indeed, *optimism bias* leads to overestimating potential positive outcomes [7]. Participating in #ShutDownSTEM was encouraging but should not eclipse the labour needed for sustained, cultural change. Perhaps we can be hopeful, but not self-congratulatory; the *self-serving bias* refers to when people give themselves credit for successes and attribute shortcomings to external factors [8]. It is difficult to recognize the roles that we have played in reinforcing the status quo in science, either by our actions or inactions.

Following the talk, there was continued engagement– my colleagues and I received requests for resources, slides, and suggestions for actions, indicating a likelihood of continued momentum. However, research on *responses to discrimination* shows that although people expect that they will confront injustice actively, they tend to do little or nothing [9]. Further, concerning racial justice, intent matters far less than impact [10]. In the future, it will be critical to continue the equity dialogue between social and natural scientists, as we continue to strive for inclusive excellence. It will also be imperative for us to engage in self-reflexivity, asking where our voices can be most useful in combatting injustice. When we find ourselves hiring research assistants, reviewing scholarship applications, or writing reference letters, we must intentionally challenge ourselves to acknowledge our biases (implicit or explicit) and work toward dismantling them – our sciences depend on it.

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An Introduction to Physics Community Leaders in Canada: Mini-Profiles / *Une introduction aux leaders de la communauté physique au Canada : Mini-profils*

Leaders in our community provide their answers to the simple question: "Why does the physics community in Canada need to be inclusive in order to be excellent?" We hope that you find their answers inspiring, and as you read the issue, will be able to form your own response in turn. Together, we can build a stronger community for future generations of physicists in Canada.

Des leaders de notre communauté répondent à une question simple : "Pourquoi la communauté des physicien(ne)s au Canada doit-elle être inclusive pour être excellente ?". Nous espérons que leurs réponses vous inspireront et qu'en lisant ce numéro, vous serez en mesure de formuler votre propre réponse à votre tour. Ensemble, nous pouvons bâtir une communauté plus forte pour les futures générations de physicien(ne)s au Canada.

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Hilding Neilson (he/him) is an interdisciplinary scientist, whose research focuses on stellar astrophysics and on the intersection of science, astronomy and Indigenous knowledge. He is Mi'kmaq and a member of the Qalipu First Nation.

Why does the physics community in Canada need to be inclusive in order to be excellent?

Mi'kmaw Elders Albert and Murdena Marshall brought the concept of Two-Eyed Seeing to western science. Two-Eyed Seeing is the practice of understanding phenomena through one lens of western science and one lens of Indigenous understanding. When put together, we gain a deeper understanding of phenomena than if we use western science alone or use Indigenous ways of knowing alone. When we are not inclusive then we simply end up exploring physics through just one lens. Because Physics in Canada is not inclusive we lose the benefit the experiences, ideas, and knowledges of the people excluded and it has always been this way. If physics was historically inclusive, can you imagine the discoveries and contributions that would have been made by Black physicists or by Indigenous physicists? Can you imagine what we, as a community, would have learned from Black and Indigenous Physicists? But, physics is not inclusive and never was. We need to be inclusive because inclusion is excellence.

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Lebohang Moleko is a Lesotho diplomat. Among the many positions he has held throughout his career, he has served as Lesotho's Ambassador to the United States and as Permanent Representative to the United Nations in New York. He served as President of the UNICEF Executive Board at the international level in 2004.

Why does the physics community in Canada need to be inclusive in order to be excellent?

Diversity and inclusivity are key in achieving excellence as this enables an exchange of new ideas. About fifty years ago, it was rare to have female physics students let alone professors, now women represent 20% of the tertiary level physicists.

Following the brutal and racist murder of George Floyd in the US, the Black Lives Matter movement has ignited action for change on a global level. Currently, many institutions are taking a tokenistic approach by hiring black person's in high profile and visible positions in order to be perceived as diverse and inclusive. Although the physics community is not in the average person's scope, it is imperative to have black representation.

A good start would be training primary and secondary educators to motivate black students to study the sciences. Good teaching can attract more black post-secondary physics students. The physics community must make a concerted effort to create more meaningful and diverse spaces for black people and other people of colour in order to achieve excellence.

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Lindsay LeBlanc is an experimental atomic physicist working with ultracold atoms and quantum technologies at the University of Alberta, situated in Treaty 6 territory. She is also a mom, a sister, a partner, and a daughter; she is queer; and she embraces all of her identities with joy.

Why does the physics community in Canada need to be inclusive in order to be excellent?

Inclusivity is not a means to an end. Whether people bring different opinions, skills, and experiences to our community is not the point; whether we get "better physics" because we are diverse is not a righteous motivation. The physics community should be inclusive because we value the humanity of the people who are keen to learn and practice physics. In our quest for understanding the principles governing our physical world, let us not forget the individuals on this journey; let us welcome all who seek to join us with open arms. Though physics may exist outside of our humanity, we can only approach it through a human lens, a lens that is uniquely shaped by each of our histories. Whether someone pursues physics for its sheer beauty or for its potential to enable new technologies, whether the systems we have set up mean they earn D's or A+'s or Nobel prizes: it is not for us to stand in anyone's way. The physics community should be inclusive for the same reason every human community should be inclusive — because it is the path towards justice.

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Lisa Cole is the Director of Programming — K2I Academy, Lassonde School of Engineering at York University. She is a passionate educator and system leader, committed to equity, diversity and inclusion in STEM. Lisa is an award-winning physics and mathematics teacher with diverse experiences including President of the Ontario Association of Physics Teachers, Science & Technology Program Facilitator for Durham District School Board, and Education Officer at the Ontario Ministry of Education.

Why does the physics community in Canada need to be inclusive in order to be excellent?

If physics is a field of study that provides unlimited opportunities to explore, discover and ultimately create solutions to societal challenges, then inclusivity in the physics community is a critical component for its success. Inclusion goes beyond inviting those who are under-represented in our field. Rather, it requires constructing a new space — a creative space that respects diverse perspectives, values unique ways of knowing and makes room for individuals with unusual skill sets. Creating inclusive solutions for humanity requires a physics community that believes there is strength and unity to be found in diversity.

Diversity matters but does not happen by chance. Anyone who knows me will tell you that I love teaching physics. It is my true passion. What people may not know however, is that I came to physics by chance — as an outsider. We must no longer rely on chance. We must foster environments in which under-represented students thrive in physics. Inclusive curriculum-based STEM programming can provide that kind of open-ended environment.

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Marie D'Iorio is a Senior Strategy Advisor at the University of Ottawa. Dr. D'Iorio is a Past-President of the Canadian Association of Physicists and served as President of the Academy of Science of the Royal Society of Canada. She leads NanoCanada, a not-for-profit network in advanced materials and nanotechnology.

Why does the physics community in Canada need to be inclusive in order to be excellent?

With the challenges facing our planet, can we afford not to rise to a new standard of excellence which is inclusive? I feel a sense of urgency (and the despair of not getting there fast enough) to embrace different if not disruptive approaches, to seek understanding of other knowledge systems (like those of our Indigenous people), to collaborate across disciplines/Faculties/Institutions, to train the next generation of physicists to help save the planet, and to drive for more immediate impact of our work. While this is not necessarily practical for all research endeavours, we have much to learn from our Arts, Humanities and Social Sciences colleagues who are adept at crossing disciplinary boundaries and effecting change in society-take, for example, ethical and legal considerations of artificial intelligence. I believe that the richness that stems from inclusion can only raise the bar of excellence. '**TOUTES** les mains à la pâte' as we say in french!

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Mubdi Rahman is a Research Associate at the Dunlap Institute for Astronomy and Astrophysics at the University of Toronto. His research interests span a wide range of data-intensive astronomy from understanding the formation of stars to the structure of matter on cosmic scales. He is an advocate for the community engagement with science, through astronomy.

Why does the physics community in Canada need to be inclusive in order to be excellent?

Growing up as a kid of immigrant parents in Northwest Toronto in the 1990s, we had a set of Golden Book Encyclopedias that had been passed on to us. One of the volumes contained an entry on race which broke all of humanity up into the "scientific" categorizations of "Caucasoid, Mongoloid, and Negroid". I had internalized this racist and wildly inaccurate concept for much longer than I'm willing to admit, long before I learned of the history of scientific racism and the horrors of eugenics. Advocates of this theory crossed scientific disciplines, including many celebrated physicists.

Physics, at its best, can improve our understanding of the universe and better the human condition. At its worst, however, physics can provide scientific cover for some of the most damaging notions in humanity. Historically, we've seen both.

We need an inclusive Canadian Physics community as to quickly identify when we're chasing these false flags, and to make sure we're building a body of knowledge that is open and accessible to all of our diverse communities throughout Canada.

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Dr. Nadia Octave is a clinical medical physicist in radiation oncology. Her current challenge is to build from blueprints to full operation, a new cancer centre that values each individual (patients and healthcare professionals). Her interest also involves IGRT, adaptive RT, radiation protection and new clinical tools for brachytherapy.

Why does the physics community in Canada need to be inclusive in order to be excellent?

Physics is the field of science that understands, models and explains nature in all its subtle ways. The questions that physics tackle are universal and require a multi-angle collective effort in order to be successfully answered. Canada is a country with rich and diverse pool of scientists. As Dr. Shohini Ghose once said "the next Marie Curie might be among us" and we do not want to miss that opportunity. In order to maximize the possibility in finding that next extraordinary individual, the Canadian physics community needs to actively create a safe, encouraging space, invite all individuals of all race, gender, origin, sexual orientation, religion, physical status to contribute to the scientific conversation where innovative expressions are welcomed, valued and respected. But inviting is just the start. We need to be more assertive in the support we provide to retain and encourage all our scientists. It is not a question of "either/or" — to solve the complex questions at hand we need a *diversity of excellence*, and that can only be achieved by tapping into all our resources, not just those that fit our perceptions. Only by combining multiple perspectives are we likely to both understand the multi-variate problems we face and find the optimal solutions to them.

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Renée Hložek is an Assistant Professor in the David A. Dunlap Department of Astronomy and Astrophysics, and the Dunlap Institute at the University of Toronto. Her research focuses on understanding what the Universe is made of, its structure and how it is changing with time. Originally from South Africa, Hložek is grateful and proud to be living and working in Canada.

Why does the physics community in Canada need to be inclusive in order to be excellent?

One of the greatest drivers in my life is the belief that physics can help us understand the natural world quantitatively. Another is that the right to ask, and answer, questions about the nature of the cosmos belongs to all people. In order to ensure that right for all Canadians, we need to build a physics community that looks like Canada. I believe that the Canadian physics community needs to be inclusive *because all people deserve the chance to be physicists* if that is their dream. We should not only push for inclusivity in pursuit of excellence, we should push for it as a foundation of equity — then excellence will follow. We need a community that truly supports and empowers all people to unravel the mysteries of the Universe. We must create a community that takes into account the needs and perspectives of those within it. If we can do this, we will become more flexible in our thinking, more open to new ideas and better able to solve fundamental problems in physics.

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Ryan Cole is a legally blind graduate student and Vanier Scholar studying under the supervision of Dr. Aaron Slepkov in the Department of Physics and Astronomy at Trent University. His research involves both theoretical and experimental work in the field of nonlinear optical microscopy.

Why does the physics community in Canada need to be inclusive in order to be excellent?

As a legally blind student pursuing a doctoral degree in materials science, I have had to overcome many unique and interesting challenges. I have learned that teamwork, an openness to accommodate others, and a willingness to try creative and unconventional solutions are critical in overcoming the greatest of barriers. My aspirations of studying physics beyond high school would have ended if I failed to find a university open to instructing a legally blind student in physics. Instead, the inclusiveness of the physics department at Trent University, and of the broader physics community in Canada, has helped me follow my passion, excel as an academic, and change people's perceptions of students with disabilities. The physics community in Canada needs to be inclusive, supportive, and creative to ensure that all its members, regardless of their individual backgrounds or circumstances, are able to achieve the highest level of success. This is vital in ensuring a strong and diverse Canadian physics community.

SARA MAZROUEI, PHD
Ryerson University
sara.mazrouei@gmail.com

Dr. Sara Mazrouei is a planetary scientist, educational developer and a science communicator. Sara is passionate about increasing the status of women and minorities in STEM as well as equity, diversity and meaningful inclusion. She is the co-founder of Women in Space Conference and currently works as an Educational Developer in STEM at Ryerson University.

Why does the physics community in Canada need to be inclusive in order to be excellent?

In physics, we want to solve cutting-edge problems, and to do that we need everybody at the table. If we don't provide more access to have everyone at the table, then we might miss the mind that has the solution. It is not enough to encourage young people to go into STEM fields if they cannot see themselves in that environment. Diversity means seeing yourself reflected, being included, and being provided with access to achieve your true full potential. It means having the opportunity to pursue careers beyond the stereotypes of your community. Women and minorities often face many micro-aggressions, death by a thousand cuts. It's a chilly climate in physics for us and the imposter syndrome is real, because we have been told for so long that we don't look like scientists, that we don't belong or we don't fit in. We need to break down barriers and remove stereotypes, starting by identifying and addressing our own implicit bias.

VICTORIA KASPI
McGill University
vkaspi@physics.mcgill.ca

Victoria Kaspi CC, FRS, FRSC studies neutron stars and fast radio transients at McGill University, where she holds the Lorne Trottier Chair in Astrophysics and Cosmology, and a Distinguished James McGill Professorship.

Why does the physics community in Canada need to be inclusive in order to be excellent?

The scientific research enterprise is both highly challenging and of utmost importance to society. Addressing our problems and puzzles, many of which lie on the borders of traditional research domains, demands the attention of the best minds bearing a diverse range of skills, experience and point of view. Inclusivity is a cornerstone of diversity. Without it we risk staid, conservative thinking, and can miss solutions that could be borne of creativity and thinking outside the box. The research community has a responsibility to the citizens that rely upon us to do our utmost to solve society's challenges using novel science, technologies and ways of thinking. Inclusivity is a key to doing this job properly and hence ensuring a healthy, safe future for all of us.

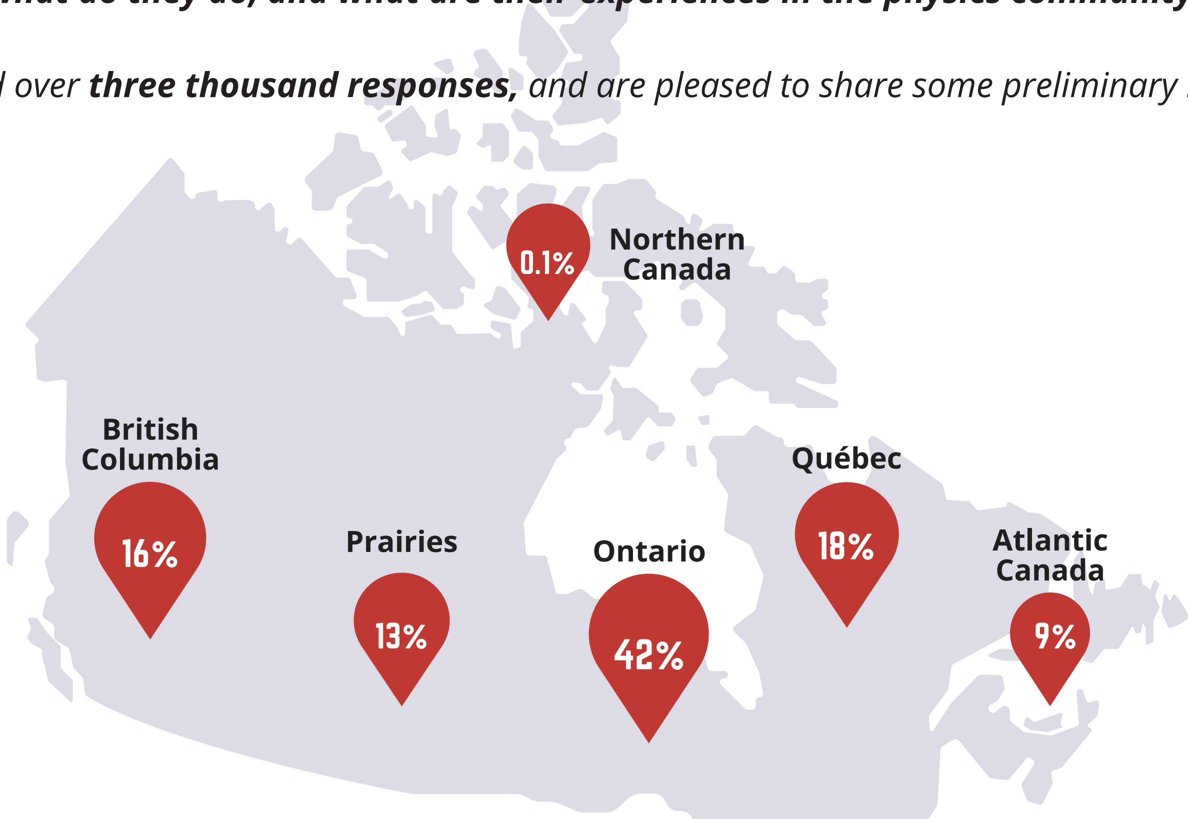
MINI PROFILES

CANPHYSCOUNTS

THE FIRST CANADA-WIDE EQUITY, DIVERSITY & INCLUSION IN PHYSICS SURVEY

*We conducted an online survey of physicists in Canada using a snowball method of recruitment. The objective was to answer three main questions: **who are the physicists in Canada, what do they do, and what are their experiences in the physics community?***

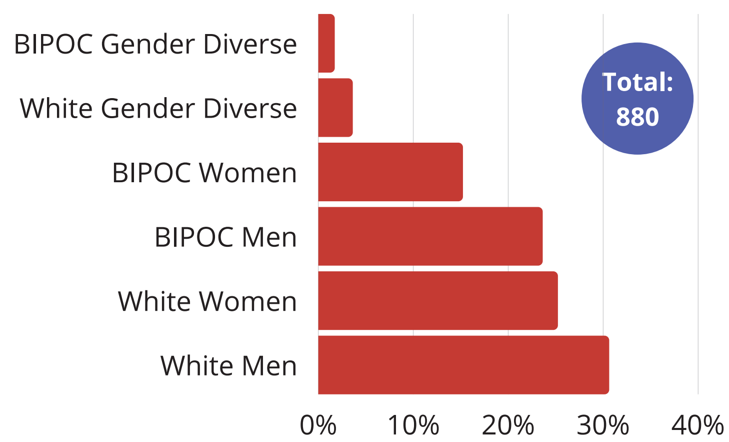
*We received over **three thousand responses**, and are pleased to share some preliminary results here.*



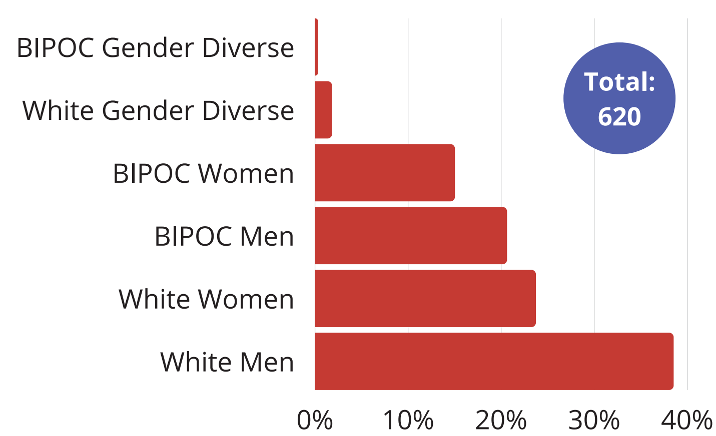
This survey was organized with approval from the Dalhousie University Research Ethics Board (File #2020-5261) in partnership with the Canadian Association of Physicists, which helped to circulate the survey and provided software. Data analysis was performed by the Laurier Centre for Women in Science (WinS).

WHO ARE OUR SURVEY RESPONDENTS?

UNDERGRADUATE STUDENTS



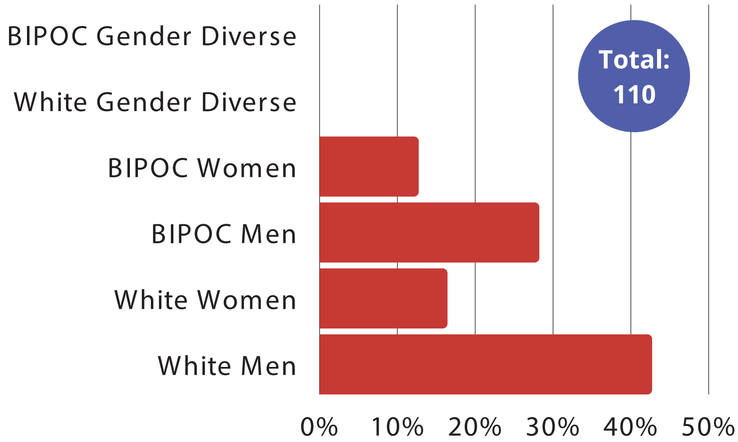
GRADUATE STUDENTS



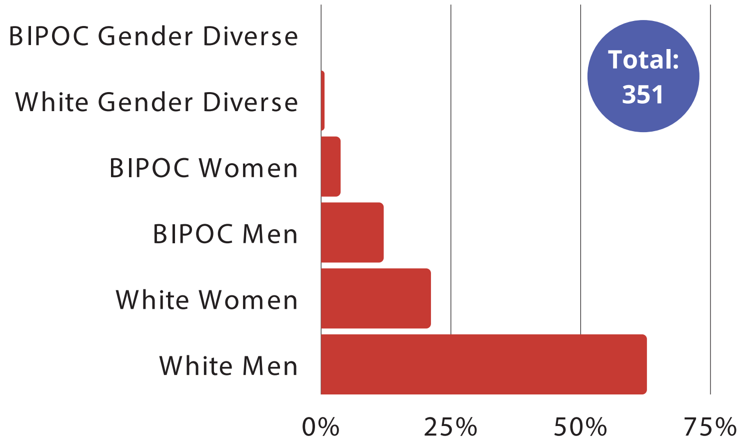
Note: BIPOC refers to Black, Indigenous, and People of Colour. Gender Diverse includes those who identified as non-binary, gender non-conforming, genderqueer, transgender (only if man or woman not specified as gender identity), and those who preferred to self-describe another gender identity.

**This method is not intended to yield a fully representative sample of the physics community, and the data should not be interpreted as such.*

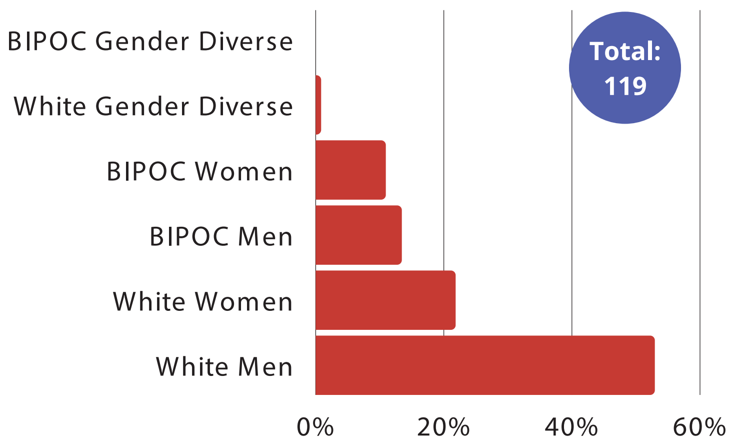
POST-DOCTORAL RESEARCHERS



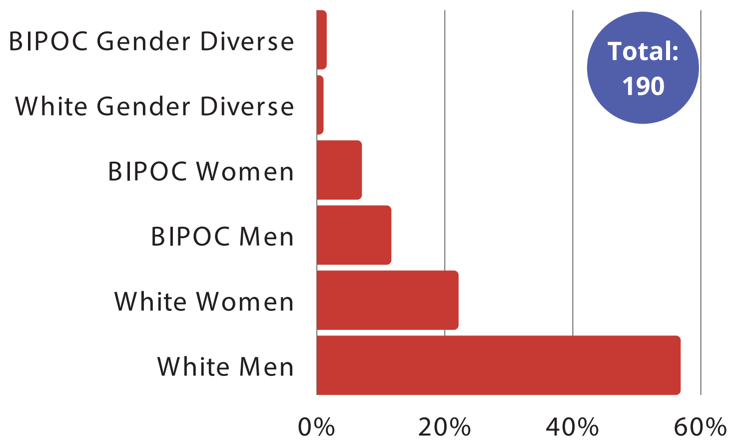
FACULTY MEMBERS



RESEARCH INSTITUTES

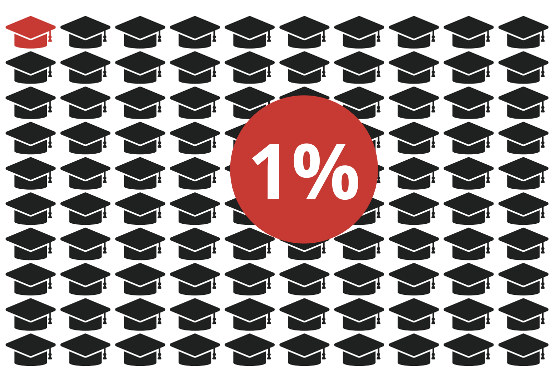


INDUSTRY & GOVERNMENT



Only 1% of respondents identified as Black

The largest group of respondents in all categories were White men



Our team is made up of physicists and social scientists with expertise in equity, diversity, and inclusion initiatives. If you have any questions about the survey project or want to contribute, please contact us at **www.canphyscounts.ca.**

Anastasia Smolina, Survey Co-Lead
Dr. Shohini Ghose, WiNS Team Lead
Adrianna Tassone, Survey Data Analyst
Skye Hennessey, Project Manager
Dr. Kevin Hewitt, Survey Co-Lead
Dr. Eden Hennessey, Survey Analysis Lead
Dr. Alexander Jay, Survey Data Analyst

WOMEN IN SCIENCE

DALHOUSIE UNIVERSITY

Canadian Association of Physicists
Association canadienne des physiciens et physiciennes

PhD Physics Degrees Awarded in Canadian Universities*
Doctorats en physique décernés par les universités canadiennes*

December 2019 to December 2020 / Décembre 2019 à Décembre 2020

Carleton University

BOURGOUIN, A., "Determination of Wair value in high energy electron beam", (M. McEwen), October 2020, pursuing a Postdoctoral Fellowship at Physikalisch-Technische Bundesanstalt, Germany.

CHRISTIANSEN, E., "A Framework for the Robust Delivery of Respiratory Motion Adaptive Arc Radiotherapy", (E. Heath), October 2020, now a Medical Physics Resident at Lakeridge Health, Ajax, ON, Canada.

MAJTENYI, N., "Improved Arterial Input Function For Dynamic Contrast-Enhanced Magnetic Resonance Imaging Using Phase and T1 Measurements", (I. Cameron), February 2020, now a Medical Physics Resident at Grand River Hospital, Kitchener, ON, Canada.

MANWELL, S., "Data-Driven Patient Motion Compensation in Cardiac Positron Emission Tomography", (T. Xu), October 2020, now a Software Developer/Physicist at Convergent Imaging Solution, Ottawa, ON, Canada.

MARTINOV, M., "Heterogeneous multiscale Monte Carlo models for radiation therapy using gold nanoparticles", (R. Thomson), February 2020, pursuing a Postdoctoral Fellowship at Robart Institute in London, ON, Canada.

Dalhousie University

HONGYANG, L., "Studies of Ni-Rich Positive Electrode Materials for Lithium Ion", (J. Dahn), May 2020, now a Sr. Cell Materials Engineer, Telsa Canada, Toronto, ON, Canada.

LEE, C., "Describing the Global Distribution and Health Response of Particulate Matter Using Modern Computational Tools", (R. Martin), October 2020, now a Physical Scientist at Environment and Climate Change Canada, Halifax, NS, Canada.

RAMANCHANDRAN, A., "Quantum State Preparation Using Chirped Laser Pulses in Semiconductor Quantum Dots", (K. Hall), October 2020, now an Optical Scientist at Rayleigh Solar Tech., Dartmouth, NS, Canada.

ROTERMUND, K., "Exploring Infrared-bright Sources Detected by the South Pole Telescope Lensing Galaxies and the Most Massive Structures in the Universe", (S. Chapman), May 2020, now pursuing a Postdoctoral Fellowship at Lawrence Berkeley National Lab in Berkeley, California, USA.

McMaster University

ALESSI, M., "Connecting the Observed Properties of Exoplanet Populations to Their Formation", (R. Pudritz), November 2020, now a Junior Data Scientist at Hamilton Health Sciences, Hamilton, ON, Canada.

BEAMIS, A., "Variations in Dense Gas and Star Formation in Nearby Galaxies", (C. Wilson), November 2020, now pursuing a Post-doctoral fellowship at Leiden Observatory, Leiden University, Leiden, The Netherlands.

HAYMAN, P., "Point-Particle Effective Field Theory and the Helium Ion", (C. Burgess), November 2020, now pursuing a Post-doctoral fellowship at The University of Auckland, Auckland, New Zealand.

LIANG, J., "Spectroscopic Studies on 39-Ca for Classical Nova Endpoint Nucleosynthesis", (A. Chen), November 2020, now pursuing a Post-doctoral research fellowship at TRIUMF, Vancouver, BC, Canada.

MAHARAJ, D., "Neutron Studies on Rare-Earth and Double Perovskite Magnetic Oxides with Frustrated Tetrahedral Architectures", (B. Gaulin), June 2020, now pursuing a Post-doctoral fellowship at TRIUMF, Vancouver, BC, Canada and the University of Windsor, Windsor, ON, Canada.

NIVEN, J., "Mechanical and Fluid Instabilities in Thin Polymer Films", (K. Dalnoki-Veress), June 2020, now pursuing a Post-doctoral fellowhip at MesoMat, Hamilton, ON, Canada.

PSALTIS, A., "Radiative Alpha Capture on 7Be with DRAGON at vp-process Nucleosynthesis Energies", (A. Chen), November 2020, now pursuing a Postdoctoral Researcher position at the Technische Universität Darmstadt, Darmstadt, Hesse, Germany.

ROBERTS, I., "Galaxy Clusters and Their Role in Galaxy Evolution", (L. Parker), November 2020, now pursuing a Post-doctoral fellowship at Leiden Observatory, Leiden University, Leiden, The Netherlands.

ROSE, M., "Single Molecule Fluorescence Microscopy Image Analysis for the Study of the 2D Motion of Cellulases and Bcl-2 Family Proteins", (C. Fradin), November 2020, now pursuing a Postdoctoral Researcher position at Tracery Ophthalmics, Toronto, ON, Canada.

ZALAVARI, L., "Size Matters: Reduction of Nuclear-Size Related Uncertainties in Atomic Spectroscopy", (C. Burgess), November 2020, now searching for employment.

Polytechnique Montréal

BELLEMARE, J., « Fragilisation par hydrogène de l'acier 4340 électroplaqué : test non destructifs électromagnétiques et analyses avancées de mesures de spectroscopie à désorption thermique », (F. Sirois / D. Ménard), December 2019, now searching for employment.

BERGERON, L.-A., "Raman Scattering From Hyperbolic Phonon-Polaritons in 2D Materials", (S. Francoeur / R. Leonelli), August 2020, now searching for employment.

FORTIN-DESCHÊNES, M., "Real-Time and Atomic-Level Studies of the Growth, Phase Transformations and Stability of Two-Dimensional Pnictogens", (O. Moutanabbir), July 2020, now pursuing a Postdoctoral Fellowship at Yale University, New Haven, Connecticut, USA.

FOURNIER-LUPIEN, J.-H., « Étude de la dynamique du quench dans différentes architectures de rubans supraconducteurs à haute température critique », (F. Sirois / M.Wertheimer), November 2020, now pursuing a Postdoctoral Fellowship at Polytechnique Montréal, Montreal, QC, Canada.

GUERBOUKA, H., "Enabling Real-Time Terahertz Imaging with Advanced Optics and Computational Imaging", (M. Skorobogatiy), December 2019, now pursuing a Postdoctoral Fellowship at Brown University, Rhode Island, USA.

LAN, T., "Organic Ion-Gated Transistors", (C. Santato), October 2020, now searching for employment.

LENGAIGNE, J., "Icephobicity of Superhydrophobic Surfaces Under Atmospheric Icing, the Role of Surface Wettability on Impact mpact Dynamics and Ice Growth Kinetics", (J. Sapieha / L. Martinu), May 2020, now pursuing a Postdoctoral Fellowship at École de Technologie Supérieure, Montréal, QC, Canada.

MORIN, A., « Fort couplage photon-magnon d'échantillons ferromagnétiques dans des cavités hyperfréquences : application aux réseaux de nanofils ferromagnétiques », (D. Ménard), December 2020, now searching for employment.

MUSONGELA, M., « Implantation d'un modèle de fuite B1 hétérogène avec la méthode des caractéristiques(MoC) », (G. Marleau), December 2019, now searching for employment.

SU, R., "Electrochemical Studies on the Biopigment Eumelanin", (C. Santato), August 2020, now searching for employment.

Queen's University

ALEXANDER, K., "End-to-End Quality Assurance of Complex Radiation Therapy Treatments", (L.J. Schreiner / T.R. Olding), June 2020, now pursuing a residency in medical physics at Kingston Health Science Centre, Kingston, ON, Canada.

BROSSARD, A., "Optimization of Spherical Proportional Counter Backgrounds and Response for Low Mass Dark", (G. Gerbier / I. Giomataris), June 2020, now pursing a postdoctoral fellowship at Queen's University, Kingston, ON, Canada.

GHAITH, M., "Development of Low-Energy Calibration Techniques for SuperCDMS using LEDs Operated Cryogenic Temperatures", (W. Rau), June 2021, now a Senior Instructor of Physics at Abu Dhabi University, Abu Dhabi, UAE.

INAYEH, A., "Molecular-Level Study of N-Heterocyclic Carbenes: Binding Modes and Self-Assembly on Au(111)", (A.B. McLean), November 2020, now working in research and development at Canadian Bank Note, Ottawa, ON, Canada.

LAM, I., "Search for Invisible Nucleon Decay in SNO+ with Improved Sensitivity", (A.J. Wright), June 2021, now pursuing a postdoctoral fellowship at Carleton Univerisity, Ottawa, ON, Canada.

LIU, Y., "Neutron Measurements and Reactor Antineutrino Search with the SNO+ Dectector in the Water Phase", (M.C. Chen), November 2020, pursuing a postdoctoral fellowship at the University of British Columbia, Vancouver, BC, Canada.

VAZQUEZ DE SOLA FERNANDEZ, F., "Solar KK Axion Search with NEWS-G", (G. Gerbier), November 2020, now pursuing a postdoctoral fellowship at IMT Atlantique Bretagne-Pays de la Loire Campus de Nantes, Nantes, France.

Ryerson University

FADHEL, M., "Photoacoustic imaging for monitoring vascular disrupting agents", (M. Kolios), October 2020, now a Diagnostic Medical Physics Resident at Yale New Haven Health, New Haven, Connecticut, USA.

HYSI, E., "On the development of photoacoustic imaging biomarkers for cancer treatment monitoring", (M. Kolios), June 2020, now a Banting and KRESCENT Fellow at Division of Nephrology, St. Michael's Hospital and Li Ka Shing Knowledge Institute, Toronto, ON, Canada.

JAFARI SOJAHROOD, A., "Classification of the nonlinear dynamics of ultrasonically excited bubbles and their effect on the acoustical properties of the medium: theory, experiment and numerical simulations", (M. Kolios / R. Karshafian), June 2020, now a Postdoctoral Fellow at Ryerson University, Toronto ON, Canada.

LI, Y., "Large-pitch methods for 2D/3D synthetic transmit aperture ultrasound imaging", (Y. Xu, M. Kolios), October 2020, now a Postdoctoral Fellow at Ryerson University, Toronto, ON, Canada.

MOMIN, S., "On optimization of mixed photon energy beams in volumetric modulated arc therapy", (R. Khan, J. Grafe), October 2020, now a Medical Physics Resident at Emory University School of Medicine, Atlanta, Georgia, U.S.A.

NGYUEN, J., "In vivo detection of lanthanum via x-ray fluorescence", (J. Grafe), October 2020, now pursuing a Postdoctoral Research Fellow at the University of Victoria, Victoria, BC, Canada.

Simon Fraser University

AKINTOLA, K., "Muon Spin Rotation/Relaxation Studies of the Kondo Insulator SmB6", (J. Sonier), June 2020, now a Patent Specialist at Marks & Clerk, Toronto, ON, Canada.

AZARI, M., "Valleytronics of Quantum Dots of Topological Materials", (G. Kirczenow), June 2020, N/A.

BAGHERI, H., "Development and Characterization of a Magnetic Particle Imaging Scanner", (M. Hayden), June 2020, N/A.

BAHRASEMANI, S., "Search for charged Higgs bosons in τ-lepton final states with 139 fb^(-1) of proton-proton collision data recorded at √S=13 TeV with the ATLAS detector", (D. O'Neil), June 2020, N/A.

CORDOBA, C., "Potential Mapping of Growth Sequence in Semiconductor NW p-n junctions", (K. Kavanagh), June 2020, N/A.

GRAHAM, S., "Modifying spin di˙usion in a nondegenerate ultracold gas", (J. McGuirk), June 2020, N/A.

HERRMANN, C., "In-situ Observations of Hexagonal Boron Nitride Growth on Cu (110)", (K. Kavanagh), October 2020, now a Field Service Engineer at Systems for Research, Kanata, ON, Canada.

LI, Y., "Probing Primordial Magnetic Fields with the Cosmic Microwave Background", (L. Pogosian), June 2020, N/A.

MATSE, M., "Mathematical Modelling of Electrokinetic Phenomona in Soft Nanopores", (M. Kennett), June 2020, N/A.

MOHTASHEMI, L., "Test of Fermi Liquid Theory with Terahertz Conductivity Measurements of MnSi", (J.S. Dodge), October 2020, N/A.

NIU, F., "Application of position sensitive detector in nuclear well logging tools", (D. O'Neil), June 2020, N/A.

SAHOTA, D., "Photoexcitation Spectroscopy of Insulating Cuprates", (J.S. Dodge), June 2020, now a Member Representative at the Teaching Support Staff Union, Burnaby, BC, Canada.

Université de Montréal

BEAUDIN, G., « Les polarons magnétiques et la phase nématique dans l'Eu1-xCaxB6 », (A. Bianchi), décembre 2020, now a Postdoctoral Research Associate, Université de Montréal, Montréal, QC, Canada.

BEDARD, C. A., « L'information algorithmique en physique : Émergence, sophistication et localité quantique », (G. Brassard et L. Vinet), mars 2020, now pursuing a Postdoctoral Fellowship at Università della Svizzera italiana, Lugano, Ticino, Switzerland.

BILLOUD, T., "Characterization of the radiation field in ATLAS using Timepix detectors", (C. Leroy), mars 2020, maintenant chercheur postdoctoral à l'IEAP (Institute for Experimental and Applied Physics) de la CTU (Czech Technical University) à Prague, Czech Republic.

DUROCHER-JEAN, A., « Diagnostics spectroscopiques de plasmas d'argon à la pression atmosphérique en présence d'espèces réactives », (L. Stafford), juin 2020, now an R&D Scientist at Optina Diagnostics, Montréal, QC, Canada.

FREUND, B., "Search for resonant WZ production in the fully leptonic final state with the ATLAS detector", (G. Azuelos and J.-F. Arguin), mars 2020, now a Data Scientist at Shopify, Montreal, QC, Canada.

GAGNON, L.-G., "Searching for supersymmetry using deep learning with the ATLAS detector", (J.-F. Arguin), décembre 2020, now pursuing a Postdoctoral Fellowship at UC Berkeley, California, USA.

LANDRY, A., « Études sur l'interaction des particules quantiques avec la gravitation », (F. Hammad), décembre 2020, maintenant sans emploi et à la recherche d'une bourse postdoctoral.

LEMAY, J.-M., « Polynômes Orthogonaux : Processus limites et modèles exactement résolubles », (L. Vinet), mars 2020, maintenant Professeur, Collège international des Marcellines, Montréal, QC, Canada.

NGUYEN, T., “From Electron Reconstruction and Identification to the Search for Supersymmetry at the ATLAS Experiment”, (J.-F. Arguin), juillet 2020, now a Software Developer at Vanilla Forums, Montreal, QC, Canada.

TREMBLAY, B., « Assimilation des données et apprentissage profond pour la prédiction de l’activité solaire à court terme », (A. Vincent), mars 2020, now a Postdoctoral Research Fellow, Laboratory for Atmospheric and Space Physics, Boulder, Colorado, USA.

Université de Sherbrooke

BERTRAND, S., « Génération et détection de la polarisation de vallée optique dans les semimétaux de Weyl », (I. Garate et R. Côté), Août 2020, maintenant Professionnel de recherche, Université de Sherbrooke, Sherbrooke, QC, Canada.

CAMIRAN-LEMYRE, J., « Ingénierie de systèmes quantiques pour une mise à l’échelle compatible aux plateformes industrielles de microélectronique », (M. Pioro-Ladrière), Décembre 2019, maintenant Président, Nord Quantique, Sherbrooke, QC, Canada.

DI PAOLO, A., « Qubits supraconducteurs protégés basés sur des modes à haute impédance », (A. Blais), Juin 2020, now pursuing a Postdoctoral Fellowship at MIT, Cambridge, MA, USA.

HARDY, G., « Études des effets de proximité dans les hétérostructures de Pr2-x Cex CuO4 et le LaFeO3 », (P. Fournier), Septembre 2020, présentement sans emploi, en réflexion.

KRISHNA, A., « Portes tolérantes aux fautes pour les codes produits d’hypergraphes », (D. Poulin), Février 2020, now pursuing a Postdoctoral Fellowship at Stanford University, Stanford, California, USA.

PRÉMONT-FOLEY, A., « Réseaux de tenseurs et solutionneurs d’impureté pour la théorie du champ moyen dynamique », (D. Sénéchal), Juillet 2020, maintenant stagiaire postdoctoral, Université de Sherbrooke, Sherbrooke, QC, Canada.

ROCHETTE, S., « Accélérer la mise à l’échelle des processeurs quantiques avec les boîtes quantiques à grilles », (M. Pioro-Ladrière), Septembre 2020, maintenant Coordonnatrice, Institut quantique (UdeS), Sherbrooke, QC, Canada.

THIBAULT, K., « Effets de rétroaction du bruit dans un circuit électrique », (B. Reulet), Janvier 2020, maintenant Coordonnateur, Institut quantique (UdeS), Sherbrooke, QC, Canada.

Université d’Ottawa

ALAM, M.Z., “Experiments in Nonlinear Optics with Epsilon-Near-Zero Materials”, (R. Boyd), October 2020, N/A.

BRITTON, M., “Isolating the gain in the nitrogen molecular cation”, (P. Corkum), December 2020, now pursuing a Postdoctoral Fellowship at Stanford University, Stanford, California, USA.

HICKEY, R., “Three-dimensional plant-derived biomaterials Scaffolds for tissue engineering and biophysical manipulation”, (A. Pelling), October 2020, now a Scientist and Project Manager at Spiderwort Inc.

SAXENA, B., “Electrostriction in As2Se3-PMMA Microtapers”, (X. Bao), December 2019, now pursuing a Postdoctoral Fellowship at the University of Waterloo, ON, Canada.

SZULAKOWSKA, L., “Electron-electron interactions and optical properties of two-dimensional nanocrystals”, (P. Hawrylak), October 2020, now pursuing a Postdoctoral Fellowship at the University of British Columbia, BC, Canada.

University of Alberta

ACHAL, R., “Fabrication and Application of Atomic Scale Silicon Structures”, (R. Wolkow), June 2020, N/A.

ARBABIMOGHADAM, S., “A Search for the Physical Basis of the Genetic Code and Modeling Cancer Cell Response to Chemotherapy Using the Ising Model”, (J. Tuszynski), Dec 2020, N/A.

BOOS, J., “Effects of Non-locality in Gravity and Quantum Theory”, (V. Frolov), Dec 2020, N/A.

CORDELL, D., “Magnetotelluric Investigation of the Laguna del Maule Volcanic Field, Central Chile”, (M. Unsworth), June 2020, N/A.

GAO, W., “Studies in Multicomponent Seismic Data Processing and Kronecker Least-Squares Reverse Time Migration”, (M. Sacchi), Dec 2020, N/A.

GARDNER, K., “Fluorescence and Lasing in Dye-doped and Conjugated Polymer Microspheres”, (A. Meldrum), Dec 2020, N/A.

HAUER, B., “On-Chip Silicon Optomechanical Cavities at Low Temperatures”, (J. Davis), June 2020, N/A.

HUFF, T., “Atomic Electronics with Silicon Dangling Bonds: Error Correction, Logical Gates, and Electrostatic Environment”, (R. Wolkow), June 2020, N/A.

KOCH, E., “Connecting Galactic to Local Scales in the Neutral Interstellar Medium Across the Local Group”, (E. Rosolowsky), Dec 2020, N/A.

LEE, B., “Improving Exploration for Geothermal Resources with the Magnetotelluric Method”, (M. Unsworth), Dec 2020, N/A.

MATHARU, G., “Strategies for Elastic Full Waveform Inversion”, (M. Sacchi), Dec 2020.

RAMP, H., “Microwave to Telecom Wavelength Transduction”, (J. Davis), Dec 2020, N/A.

REYES CANALES, M., “Probabilistic Seismic Hazard Analysis for Induced Seismicity”, (M. van der Baan), Dec 2020, N/A.

University of Guelph

GOOD, D., “Investigations of Membrane Protein Dynamics using Solid State NMR”, (V. Ladizhansky), June 2020, now a Customer Success Scientist, Nicoya, Kitchener, ON, Canada.

HARRIS, A., “Spectroscopic Characterization of Atypical Ion Pumping Microbial Rhodopsins”, (L. Brown), October 2020, Postdoctoral Fellow, now a Neurobiology Department at Weizmann Institute of Science, Rehovot, Israel.

RAHEMTULLA, A., “Resolving Short Range Order of Amorphous Solids”, (S. Kycia), June 2020, now an Associate Scientist, Canadian Light Source, SK, Canada.

SHELTON, E., “Quantifying Bacterial Motion in Twitching Colonies and the Effect of the Agar-Glass Interface on Bacterial Twitching Motility”, (J. Dutcher), October 2020, now a Data Scientist, Royal Bank of Canada, Toronto, ON, Canada.

University of Manitoba

BERGEN, R., “Optimizing and Advancing Mulit-Parametric Magnetic Resonance Imaging for Biologically - Guided Radiotherapy”, (L. Ryner, M. Essig), February 2020, N/A.

COWNDEN, B., “Gravitational Collapse in Anti-deSitter Spacetime”, (A. Frey), October 2020, N/A.

FLYNN - PRIMROSE, D., “On the Hahn and Levi - Civita Fields: Topology, Analysis and Applications”, (K. Shamseddine), February 2020, N/A.

GUEST, B., “X - Ray Observations of Pulsar Wind Nebular: The Nature of Pulsar Winds and Their Environment”, (S. Safi-Harb), May 2020, N/A.

LANG, M., “Automated Production and Purification of Hyperpolarized Xenon Gas”, (C. Bidinosti, J. Martin), October 2020, N/A.

MIKULA, P., “Gradient Flow in Holographic Superconductors”, (G. Kunstatter, M Carrington), February 2020, N/A.

MOSTAMAND, M., “Laser Developments and Study of Rydberg and Autoionizing Rydberg States in Tm, La and At Using Resonant Ionizatin Laser Spectroscopy”, (G. Gwinner, J. Lassen), May 2020, N/A.

PAIDI, V. K., “Role of Orbital Hybridization in the Magnetism of Nanoscale Oxides”, (J. van Lierop), February 2020, N/A.

SHIELLS, K., "Radiative Corrections to Semileptonic Processes in the Standard Model", (P.G. Blunden), May 2020, N/A.

University of New Brunswick

Enjilela, R, "Measurements of Porous Media: Fluid Quantification and Magnetic Susceptibility Contrast", (B. Balcom), October 2020, now a Course Instructor, Carleton University, Ottawa, ON, Canada.

Kristoffersen, S, "Doppler Michelson Interferometer Wind Observations and Interpretations", (W. Ward), May 2020, now pursuing a Postdoctoral Fellowship at CEA (Commissariat à l'énergie atomique et aux énergies alternatives), Paris, France.

University of Saskatchewan

CHOUDHURY, S, "Small-scale E-Region Irregularities in High-Latitude Plasma", (JP St-Maurice), Spring 2020, now an Entrepreneur, Real Estate Business, Saskatoon, SK, Canada.

DEBOER, T, "Advancing the Characterization of Semi Conductors with Synchrotron Radiation", (A. Moewes), Fall 2020, now a Research Associate at University of Saskatchewan, Saskatoon, SK, Canada.

HO, J, "Beyond the Conventional Quark Model: Using QCD Sum Rules to Explore the Spectrum of Exotic Hadrons", (T. Steele, D. Harnett), Fall 2020, now an Assistant Professor, at Dordt University, Sioux Center, Iowa, USA.

PALAMETA, A, "Beyone-the Quark-Model Heavy Hadrons from QCD Sum Rules", (T. Steele, D. Harnett), Fall 2020, now a Sessional Lecturer, at University of Fraser Valley, Abbotsford, BC, Canada.

SAMADI, N, "A Real Time Phase Space Beam Size and Divergence Monitor for Synchrotron Radiation", (D. Chapman), Spring 2020, now pursuing a Postdoctroral Fellowship, at Paul Scherrer Institut in Switzerland, Villigen PSI, Switzerland.

ZULKOSKEY, A, "Interdimensional Effects in Systms of Femions", (K. Tanaka, R. Dick), Spring 2020, now a Professional Specialist, at University of Saskatchewan, Saskatoon, SK, Canada.

University of Toronto

ABIDI, S. H., "Precision Higgs Boson Measurements using the H → ZZ*→ 4l Decay Channel., (R. Teuscher), November 2020", now pursuing a Postdoctoral Fellowship at ATLAS, Brookhaven National Labs (BNL), New York, USA.

BHATT, N., "Spectroscopy of Ions in Cryogenic Neutral Plasmas.", (A.C. Vutha), November 2020, now pursuing a Postdoctoral Fellowship at PTB, Institute for Experimental Quantum Metrology - Quantum Clocks and Complex Systems, Braunschweig, Germany.

CORMIER, K.J.R., "A Study of Highly-Energetic Top Quarks Using the ATLAS Detector.", (R. Teuscher), March 2020, now pursuing a Postdoctoral Fellowship at CMS experiment, University of Zurich, Zurich, Switzerland.

FAJBER, R., "Understanding the Role of Latent Heating in the Heat and Mass Transport of the Global Atmospheric Circulation.", (P.J. Kushner), November 2020, now pursuing a Postdoctoral Fellowship at University of Washington, Seattle, Washington, USA.

GUERRERO, J. M., "The Influence of Curvature on Mantle Convection Featuring a Temperature-Dependent Viscosity.", (J.P. Lowman), November 2020, now pursuing a Postdoctoral Fellowship at Institute of Earth Sciences, Academia Sinica, Taipei, Taiwan.

HARTLEY, J. W., "The SuperBIT Hardware Design and a Constraint of the Tensor to Scalar Ratio r from the Spider I Polarized CMB Maps.", (C.B. Netterfield), November 2020, now a Co-founder, StarSpec.

HAY, S., "Pattern Scaling Methods for Understanding the Response to Polar Sea-Ice loss in Coupled Earth System Models.", (P.J. Kushner), November 2020, now pursuing a Postdoctoral Fellowship at University of Toronto, Department of Physics, Toronto, ON, Canada.

LES, R., "Exotic Diboson Production in the Semileptonic Channels with the ATLAS Detector.", (W. Trischuk), March 2020, now pursuing a Postdoctoral Fellowship at Michigan State University, East Lansing, Michigan, USA (working from Geneva, Switzerland).

LI, Y., "Mainland Southeast Asia Precipitation: Natural Variability, Teleconnection, and Response to External Forcing", (D.B.A. Jones), November 2020, now looking for employment.

NINO, D.F., "On the Molecular Counting and Clustering Problems in Single-Molecule Quantitative Nanoscopy", (J.N. Milstein), November 2020, now pursuing a Postdoctoral Fellowship at University of Toronto Mississauga (UTM), Mississauga, ON, Canada.

THAM, W.-K., "Quantum Homomorphic Encryption: Implementation and Application + SPLICE: A Novel Super-resolution Imaging Technique.", (A.M. Steinberg), November 2020, now a co-founder of a start up company.

TZITRIN, I., "From the theory of entanglement to the practice of optical quantum information", (H.K. Lo), November 2020, now pursuing a Postdoctoral Fellowship at University of Toronto / Xanadu, Toronto, ON, Canada.

VELOCE, L. M., "Fiducial Inclusive and Differential Cross Section Measurements of the Higgs Boson in the H → ZZ*→ 4l Channel with the ATLAS Detector.", (R. Teuscher), November 2020, now pursuing a Postdoctoral Fellowship at ATLAS, University of Toronto, Toronto, ON, Canada.

WANG, W., "Adaptive Techniques in Practical Quantum Key Distribution", (H.-K. Lo), June 2020, now pursuing a Postdoctoral Fellowship at Waterloo/PSI, Waterloo, ON, Canada.

WOODFORD, C.J., "Centre-of-mass motion and precession of the orbital plane in binary black hole simulations.", (N. Murray), November 2020, now a full-time Knowledge Translation Specialist, Arthur B. McDonald Canadian Astroparticle Physics Research Institute / Queen's University, Kingston, ON, Canada, and a part-time (1) Dept. of Physics Sessional Lecturer, University of Toronto, Toronto, ON, Canada, and (2) Educational Content Developer, Discover the Universe / the Dunlap Institute, Toronto, ON, Canada.

ZHANG, C., "New Physics of the Standard Model and Beyond.", (B. Holdom), June 2020, now pursuing a joint Postdoctoral Fellowship at University of Toronto with University of Waterloo, ON, Canada.

University of Victoria

ALLEN, M., "Theoretical investigation of size effects in multiferroic nanoparticles", (R. de Sousa), July 2020, now searching for employment.

BOTTRELL, C., "Morphological and kinematic indicators of structural transformation in galaxies", (L. Simard / S. Ellison), July 2020, now a Kavli Fellow at Kavli Institute for the Physics and Mathematics of the Universe, Tokyo, Japan.

CHIU, J., "Search for Higgs boson decays to beyond-the-Standard-Model light bosons in four-lepton events with the ATLAS detector at the LHC", (M. Lefebvre), December 2020, now searching for employment.

DUNNING, C., "Contrast Agent Imaging Using An Optimized Table-top X-ray Fluorescence and Photon-Counting Computed Tomography Imaging System", (M. Bazalova-Carter), October 2020, now a Postdoctoral Fellow at Mayo Clinic, Rochester, Minnesota, USA.

FANTIN, N., "Studying a Fire from its Ashes: White Dwarfs as Probes of Milky Way Evolution", (P. Côté / J. Navarro), November 2020, now searching for employment.

GERARD, B., "Exoplanet imaging speckle subtraction: current limitations and a path forward", (C. Marois / J. Willis), May 2020, now a Postdoctoral Scholar at the University of California Santa Cruz, Santa Cruz, California, USA.

HANI, M., "Probing galaxy evolution through numerical simulations: mergers, gas, and star formation", (S. Ellison), July 2020, now pursuing a Herschel Fellowship at McMaster University, Hamilton, ON, Canada.

University of Windsor

OUELETTE, A., "Adaptive, High-Resolution Ultrasound Phased Array Imaging for use in the Inspection of Laser Brazed Joints in the Automotive Sector", (R. Maev), June 2020, now a Postdoctoral Fellow at the University of Windsor, Windsor, ON, Canada.

Book Review Policy

Books may be requested from the Book Review Editor, Richard Marchand, by using the online book request form at http://www.cap.ca. You must be a residing in Canada to request a book.

CAP members are given the first opportunity to request books. For non-members, only those residing in Canada may request a book. Requests from non-members will only be considered one month after the distribution date of the issue of *Physics in Canada* in which the book was published as being available.

The Book Review Editor reserves the right to limit the number of books provided to reviewers each year. He also reserves the right to modify any submitted review for style and clarity. When rewording is required, the Book Review Editor will endeavour to preserve the intended meaning and, in so doing, may find it necessary to consult the reviewer. Reviewers submit a 300-500 word review for publication in PiC and posting on the website; however, they can choose to submit a longer review for the website together with the shorter one for PiC.

La Politique Pour la Critique De Livres

Si vous voulez faire l'évaluation critique d'un ouvrage, veuillez entrer en contact avec le responsable de la critique de livres, Richard Marchand, en utilisant le formulaire de demande électronique à http://www.cap.ca.

Les membres de l'ACP auront priorité pour les demandes de livres. Ceux qui ne sont pas membres et qui résident au Canada peuvent faire une demande de livres. Les demandes des non-membres ne seront examinées qu'un mois après la date de distribution du numéro de la Physique au Canada dans lequel le livre aura été déclaré disponible.

Le Directeur de la critique de livres se réserve le droit de limiter le nombre de livres confiés chaque année aux examinateurs. Il se réserve, en outre, le droit de modifier toute critique présentée afin d'en améliorer le style et la clarté. S'il lui faut reformuler une critique, il s'efforcera de conserver le sens voulu par l'auteur de la critique et, à cette fin, il pourra juger nécessaire de le consulter. Les critiques pour publication dans la PaC doivent être de 300 à 500 mots. Ces critiques seront aussi affichées sur le web; s'ils le désirent les examinateurs peuvent soumettre une plus longue version pour le web.

Books Received / *Livres Reçus*

The following titles are a sampling of books that have recently been received for review. Readers are invited to write reviews, in English or French, of books of interest to them. Unless otherwise indicated, all prices are in Canadian dollars.

Lists of all books available for review, books out for review and book reviews published since 2011 are available on-line at www.cap.ca (Publications).

In addition to books listed here, readers are invited to consider writing reviews of recent publications, or comparative reviews on books in topics of interest to the physics community. This could include for example, books used for teaching and learning physics, or technical references aimed at professional researchers.

Les titres suivants sont une sélection des livres reçus récemment aux fins de critique. Nous invitons nos lecteurs à nous soumettre une critique en anglais ou en français, sur les sujets de leur choix. Sauf indication contraire, tous les prix sont en dollars canadiens.

Les listes de tous les livres disponibles pour critique, ceux en voie de révision, ainsi que des critiques publiées depuis 2011 sont disponibles sur : www.cap.ca (Publications).

En plus des titres mentionnés ci-dessous, les lecteurs sont invités à soumettre des revues sur des ouvrages récents, ou des revues thématiques comparées sur des sujets particuliers. Celles-ci pourraient par exemple porter sur des ouvrages de nature pédagogique, ou des textes de référence destinés à des professionnels.

GENERAL / GÉNÉRAL

The Physics of Polarized Targets, Tapio O. Niinikoski, Cambridge University Press, 2020; pp. 530; ISBN: 978-1108475075; Price: 218.95.

Theory of Simple Glasses: Exact Solutions in Infinite Dimensions, Giorgio Parisi, Pierfrancesco Urbani & Francesco Zamponi, Cambridge University Press, 2020; pp. 349; ISBN: 978-1107191075; Price: 91.95.

UNDERGRADUATE LEVEL / NIVEAU DE PREMIER CYCLE

Principles of Optics: 60th Anniversary Edition, Max Born & Emil Wolf, Cambridge University Press, 2019; pp. 992; ISBN: 978-1108477437; Price: 79.95.

The Cosmic Revolutionary's Handbook: (Or: How to Beat the Big Bang), Luke A. Barnes & Geraint F. Lewis, Cambridge University Press, 2020; pp. 286; ISBN: 978-1108486705; Price: 25.95.

Theoretical Concepts in Physics An Alternative View of Theoretical Reasoning in Physics (3d ed.) [v], Malcolm S. Longair, Cambridge University Press, 2020; pp. 636; ISBN: 9781108484534; Price: 68.95.

SENIOR LEVEL / NIVEAU SUPÉRIEUR

Invariant Imbedding T-matrix Method for Light Scattering by Nonspherical and Inhomogeneous Particles, Bingqiang Sun, Lei Bi, Ping Yang, Michael Kahnert and George Kattawar, Elsevier, 2020; pp. 262; ISBN: 978-0-12-818090-7; Price: 158.11.

Mean Field Theory, Vladimir M Kolomietz, Shalom Shlomo [v], World Scientific, 2020; pp. 588; ISBN: 978-981-121-177-5; Price: 252.95.

Pear-Shaped Nuclei, Suresh C Pancholi, World Scientific, 2020; pp. 192; ISBN: 978-981-121-759-3; Price: 121.61.

Statistics, Data Mining, and Machine Learning in Astronomy: A Practical Python Guide for the Analysis of Survey Data, Updated Edition, Zeljko Ivezić, Andrew J. Connolly, Jacob T. VanderPlas, and Alexander Gray, Princeton University Press, 2019; pp. 560; ISBN: 9780691198309; Price: 103.58.

Book Reviews / *Critiques de livres*

Further Adventures of the Celestial Sleuth, by Olson, Donald W., Springer, 2018, pp. 334, ISBN: 978-3-319-70319-0, price 32.84.

I selected this book because I was intrigued by its premise: using astronomy to solve mysteries regarding the time, date and location of the origins of works of art. As a secondary school physics teacher, I am always interested in finding other ways to teach students about the applications of the knowledge and skills we teach them in school, and this text did not disappoint.

The book reads much like a Sherlock Holmes case file. Donald W. Olson describes how he and his team from Texas State examined paintings, battles, photographs, and literature through an astronomical lens, to locate, re(examine) and challenge their understandings of the works, as well as the conclusions of other researchers. Clues, such as historical documents (*e.g.,* letters, train schedules, tide tables, newspaper clippings) are combined with modern means (*e.g.,* computer planetarium simulations), to build their own portrait, which includes information about the astronomy, as well as the artists themselves.

Broken into four parts — *Astronomy in Art, Astronomy in History, Astronomy in Literature, The Terrestrial Sleuth* — Olson begins each chapter outlining the questions he and his team had set out to solve. In Part One, the challenge was often to deduce the location and date for a painting. Olson works with an underlying assumption that the artist included an accurate representation of what was present in the night sky from their location. From this, he uses stories about the artists and other references to the work, to deduce his answers. Olson also includes in this section an examination of *Times Square Kiss* — and specifically the shadows on the buildings — to add more information to the ongoing discussion on the as-yet unidentified woman and sailor. In Part Two, the team sought to better understand the factors which influenced strategic battle preparations (such as the case for the Battle of Stirling Bridge or the Battle of Normandy), and worked with data to highlight misconceptions. Part Three focuses on literary passages, to determine their accuracy, in terms of celestial movements and season. Olson uses knowledge of each author's astronomical competence to frame the possible legitimacy of the passages, and then move on to determine whether authors had accurately described astronomical events or celestial movements based on the season or location of a scene. In the final part, Olson turns to two final puzzles: a railway and locating the Millais oak tree.

This is the second ***Celestial Sleuth*** book, and Olson makes reference to other case files in that volume — although not required to understand what is discussed here. The background knowledge required to understand the text is at the secondary level, and new material and terminology is explained succinctly to allow the reader to follow key ideas of analyses. For me, I felt it did provide some interesting options from which to teach physics at the secondary level, such as Chaucer's description of the moon's path in terms of Kepler's Laws of motion. For the higher education educator, I feel the book gives enough information to provide a roadmap of the kinds of information and tools one would need to endeavor on a similar quest.

Tasha Richardson,
Teacher, Albert Campbell CI, Toronto District School Board

On Gravity — A Brief Tour of a Weighty Subject, by Anthony Zee, Princeton University Press, 2018, ISBN: 9780691174389, price 19.95.

In the preface, Anthony Zee tells his readers that **On Gravity** is supposed to bridge the gap between popular books and textbooks on Einstein gravity. After reading the 142 pages of the main text and the eight-page appendix, I am convinced that he succeeded. The area between popular books and textbooks is somewhat of a no man's land, and especially for individuals with an interest in a particular field (say, gravity, for instance) this can be quite frustrating. What should you read when you already understand the basic idea of gravitation, know the main players in the history of its development, and have perhaps watched a few documentaries on the topic as well?

Well, you should read **On Gravity**.

The book is divided in four parts which consist of a handful of chapters each, and each chapter is again split into digestible sections with fitting and sometimes tongue-in-cheek headlines. Zee is one of the few physics authors who write so fluently and seemingly effortlessly that I didn't even realize I was already halfway through the book. His tone, as usual, is relaxed, conversational, and laid-back, making the seemingly complicated topic of Einstein's General Theory of Relativity a lot more approachable.

In part I, Zee introduces gravity as the weakest of the four fundamental forces in our Universe and explains the nature of electromagnetic (and gravitational) waves. In part II we learn about Einstein's main idea: the principle of relativity. We also learn why we shouldn't call it "principle of relativity." Part III is devoted to a detailed explanation of the action principle in both classical mechanics and gravity theory. Finally, in part IV we learn about black holes, Hawking radiation, gravitons, as well as the concepts of dark matter and dark energy. In the grand finale Zee highlights the importance of gravitational waves, which, and that's the hope, will provide scientists with new powerful methods of observing and understanding the Universe.

On Gravity takes its time with the reader, and most concepts are explained brilliantly and in quite some detail: the idea of relativity, the action principle, gravitational waves, and even curved spacetime (in the appendix). I wish more professors would read this book and use these explanations in their undergraduate courses! The explanation of Hawking radiation, on the other hand, after a thorough introduction into the quantum uncertainty principle, seems a bit rushed and barely surpasses that given in popular science texts. Moreover, what I would have liked to see (and what is lacking in Zee's treatment) is a deeper discussion of the *limitations* of General Relativity. The Evergreen, a.k.a. the quest for the still elusive theory of quantum gravity, is clearly addressed, but problems at the classical level (say, in the form of gravitational singularities inside of black holes) are not mentioned. I think this is a missed opportunity to make this book more balanced.

Overall, **On Gravity** is a fantastic read. It is supplemented by a whopping 12-page index as well as 13 pages of annotations providing additional anecdotes, insights, and kindhearted encouragements to the reader. Zee's book might be a good choice for undergraduate students who are contemplating to enter the field but don't want to read 800 pages in a standard textbook. And if you work on gravity yourself, and you want to talk to your friends a bit more about your work, give them this book. Seriously. Zee's unique style will surely entice them and present research in gravity from its truly attractive side (pun intended).

Jens Boos,
Ph.D. candidate, Department of Physics,
University of Alberta

PRACTICAL BAYESIAN INFLUENCE: A PRIMER FOR PHYSICAL SCIENTISTS, by Coryn A.L. Bailer-Jones, Cambridge University Press, 2017, pp. 295, ISBN: 9781316642214, price 105.95.

Few fields are as fraught with a history of controversy as that of Bayesian inference. Although born in the 18th century in the work of Bayes and Laplace, its "subjective" view of probability fell out of favours in the 20th century after Neyman, Pearson, and others developed statistics based on a frequentist interpretation of probability. In the former, probability measures degrees of rational belief in the truth of a proposition; in the latter, probability is viewed as the limiting frequency in an infinite number of trials.

More recently, there has been a tremendous resurgence of Bayesian methods, which are at the heart of many successful methods in data science and machine learning. With this growth in popularity has come the need to teach the methods to broader scientific audiences. However, perhaps because of its "insurgent" past, many texts have been original and quirky. Think of the books by Harold Jeffreys, Edward Jaynes, D.S. Sivia, and David MacKay for example. Perhaps what makes such books brilliant and inspirational also makes them harder to teach from. Insights that appear deep to the expert may just confuse the student. (The same critique has been made of the Feynman Lectures.)

Coryn A. L. Bailer-Jones' book is an interesting pragmatic alternative. It is straightforward and clear, if not always original — many of its examples and ways of presenting material come from the "quirky" books above. Still, it may be easier to follow than other, deeper treatments. For example, Chapter 9 goes carefully through the procedure for curve fits using Markov-Chain Monte Carlo (MCMC) and also offers a treatment of data outliers using mixture models. The latter example provides a simple way to automatically identify and, in effect, exclude "bad" points from otherwise "good" data. And the introductory discussion to model selection — clarifies many points, such as why use odds ratios, that are often glossed over in other discussions.

An attractive feature of the book is its many numerical illustrations, supported by explicit code available online. Perhaps unfortunately, the chosen language is R, an open-source program from the statistics community that is not widely used by the physics community (at least that part I am familiar with). Matlab, Mathematica, and Python are more common. Of course, these languages share common features, and transcribing a routine into your favourite language can be a good exercise. A similar critique is that the notation, for example E[x] for expectation rather than $\langle x \rangle$, reflects conventions of statistics more than physics.

In short, Bailer-Jones has written an attractively brief, direct, "practical" introduction to Bayesian Inference. While its presentation and examples are often standard, it is well organized and very clear and should be much appreciated by upper-level undergraduates looking for an introduction to the field, assuming they do not get too hung up on the use of R and statistics notation. For graduate students seeking more depth and derivations, *Bayesian Probability Theory*, by Wolfgang von der Linden, Volker Dose, and Udo von Toussaint, is a comprehensive alternative. And, for inspiration, I still prefer Sivia's *Data Analysis: A Bayesian Tutorial*.

John Bechhoefer, Simon Fraser University

The Editorial Board welcomes articles from readers suitable for, and understandable to, any practising or student physicist. Review papers and contributions of general interest of up to four journal pages in length are particularly welcome. Suggestions for theme topics and guest editors are also welcome and should be sent to bjoos@uottawa.ca.

Le comité de rédaction invite les lecteurs à soumettre des articles qui intéresseraient et seraient compris par tout physicien, ou physicienne, et étudiant ou étudiante en physique. Les articles de synthèse d'une longueur d'au plus quatre pages de revue sont en particular bienvenus. Des suggestions de sujets pour des revues à thème sont aussi bienvenues et peuvent être envoyées à bjoos@uottawa.ca.

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