Turning Tables in Physics: Utilizing Photo-Research Exhibits to Challenge Inequities and Celebrate Women in Science

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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.

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].

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

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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