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The imperative for polar education

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The polar regions are experiencing dramatic and tangible impacts due to climate change (IPCC, 2014; USGCRP, 2018). The Arctic is the first region on the planet to experience a major abrupt climate change since the onset of modern observations (Auger et al., 2019), and the region is warming twice as fast as the rest of the world. Nine of the last 10 years saw air temperatures in the Arctic of at least 1 °C warmer than the 1981–2010 mean, resulting in rapidly changing weather patterns and ice concentrations (Thoman et al., 2020). In 2020, the Arctic region experienced record high air temperatures, record low sea ice extent and snow cover, and unprecedented wildfires (Thoman et al., 2020). Across the Earth at the other pole, surface melting of ice sheets has been accelerating across the Antarctic Peninsula (Tuckett et al., 2019), threatening to accelerate ice sheet collapse (Pattyn & Morlighem, 2020).

Even though polar regions are far away from most of the world's population, they profoundly impact lower-latitude weather patterns, raise sea level, and figure prominently in the world's economy and security (National Science Foundation (NSF), 2020). The changing polar environments have created important scientific and societal concerns, including disruptions to Northern Hemisphere weather, shifting fisheries, and rising sea levels. Given these far-reaching impacts, understanding polar regions, polar processes and the connections between climate change at the poles and global climate is important for people across the world. "What happens in polar regions affects all of us" has been the theme of the 2020 International Polar Week. There is a critical imperative for polar education to reach education professionals, students of all ages, and the public. The remote polar regions and extreme conditions under which research is conducted in the Arctic provide unique opportunities for capturing the imagination of learners and the public on topics ranging from science, history, culture, economics and geography to the arts. At the same time, lack of accessibility makes it difficult to provide authentic field and at-sea research experiences for those living outside the polar regions, allowing only few scientists and many fewer teachers and students from lower latitudes to participate. Initiatives that connect the Arctic and Antarctic researchers to learners worldwide, using modern telecommunication

tools, and vetted polar education materials are two key ingredients for increasing general public polar literacy.

For over a century, the U.S. and countries across the world have invested significant resources in polar research, illustrated by large international research campaigns during the four International Polar Years (IPY) between 1882 and 2008. The U.S. intensified this investment in polar research, when in 2017 *Navigating the New Arctic* was announced as one of the agencies' ten big ideas aiming to improve observations across the Arctic, the understanding of the Arctic system, and global impacts. The Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) expedition is one example of this renewed national investment in polar research, which had a major public engagement component. This year-long expedition (2019–2020) allowed over 500 researchers from over 20 nations to collect observations and communicate findings on an on-going basis, as their research vessel, frozen in sea ice, drifted across the Arctic Ocean.

While many of the large research programs have included significant investment in public outreach and education, such as the 4th IPY (2007–2008), Study of Environmental Arctic Change (SEARCH), and MOSAiC, a large proportion of respondents on national surveys do not consider themselves informed about polar regions, and knowledge about polar regions has been and continues to be limited among the U.S. population (Hamilton, 2016; Hamilton, Cutter, and Schaefer, 2012). For example, the nationally representative 2016 *Polar, Environment, and Science* (POLES) survey showed that less than half of the U.S. public understand the location of the north and the south poles (Hamilton, 2016; Hamilton et al., 2019). Similarly, nationally representative surveys show that more than half of Americans achieve the equivalent of a failing grade on a climate knowledge survey (Ballew et al., 2019; Leiserowitz et al., 2010). However, at the same time, six out of ten Americans indicate that climate change affects their local community "a great deal" or "to some extent" (Funk & Kennedy, 2019). So, while people are aware of local impacts of a changing climate, their understanding of the climate system and related connections to polar regions is limited.

The lack of broad polar literacy among the public combined with the importance of the polar regions on the global

climate and socio-economic systems highlight the need for engaging and effective educational materials and experiences that bring polar research and findings to learners in the lower latitudes. Polar regions and topics are largely absent from educational standards and few teachers undergo training around polar topics as part of their education. Many opportunities exist through formal learning in K-16 settings and improved preparation of teachers, as well as through informal learning environments, such as museums, parks, planetariums, and nature centers in which both climate literacy and the understanding of connections between polar regions and global climate change can be highlighted. A Polar Literacy initiative, led by Rutgers University, has made progress in identifying seven Polar Literacy Principles and corresponding topics to support the work of educators and scientists to increase the public's understanding of the importance of polar regions (McDonnell et al., 2020).

This theme issue on polar education provides new research findings, instructional and outreach approaches, and assessments supporting polar education. Addressing a wide range of educational settings (informal education, K-12 settings, teacher preparation, undergraduate education), the issue includes commentaries, curriculum and instruction papers, literature reviews, and research papers.

Guthridge shares a reflection on the transition from exploration to science research to STEAM opportunities that have been supported by the National Science Foundation over decades of providing funding for fieldwork in Antarctica, and outlines opportunities for inspiring the public through collaborations of artists, educators, and researchers in the unique environment of Antarctic research stations. Several papers center around the theme of polar knowledge. *Hamilton* drilled deep into large national datasets from general public knowledge surveys that have been used for over a decade to assess public understanding of polar topics and regions. He finds that responses to some of the survey questions are not a reflection of factual knowledge that people hold, but rather are deeply intertwined with the personal socio-political identity of respondents. This commentary highlights the challenges that educators face when addressing knowledge gaps and emphasizes that climate and polar education efforts need to account for ideological barriers.

Using the popular game based Kahoot! platform *Pfirman, Hamilton, Turrin, Narveson and Lloyd* studied polar content knowledge of tens of thousands of U.S. students and found that students' knowledge of polar topics scores well below the knowledge across the U.S. population. Meanwhile, *Schloesser & Gold* found in a national teacher needs assessment that teachers themselves have a higher than average knowledge of polar topics, at the same time that they describe a need for high quality, engaging teaching resources and professional development to support their teaching of polar topics.

Multiple papers in this issue discuss effective instructional strategies and educational resources for classroom instruction. The paper from *Pfirman, Hamilton, Turrin, Narveson and Lloyd* demonstrate that Kahoots are an engaging and

popular resource to support teachers both in bringing polar topics into classrooms, as well as assessing student knowledge. *Senger & Nordmo* describe the innovative use of digital field notebooks in an Arctic field setting to support field camps with graduate and undergraduate students, and *Senger and 22 coauthors* describe the usability of high resolution digital outcrops through the Svalbox database as an effective instructional teaching tool for remote polar field settings. A series of newly developed instructional units for undergraduate students are described by *Rowe and 14 coauthors* as an effective model of guided inquiry that uses Excel and Python to analyze polar and climate change data and embed these in a variety of courses and disciplines.

Because not every student has the opportunity to go into the field in a polar region, *Pfirman, O'Garra, Bachrach Simon, Brunacini, Reckien, Lee & Lukasiewicz* explore the efficacy of games as an impactful instructional approach to teaching about polar topics and share results that show students are more engaged in game-based learning when compared to traditional instruction. They also find that, through game play, students develop a sense of agency in knowing what they can do to help protect Arctic ecosystems.

Demant-Poort and Berger describe a critical gap in teacher education around climate change in an exploratory study with preservice teachers in Greenland and Canada, despite the importance of understanding the impacts and mitigation of climate change in their home communities. They call for improving teacher professional development opportunities around climate change in polar regions, underscoring a need that teachers describe in the national survey by *Schloesser & Gold*.

As an example of bringing polar topics to the public, *Branchero, Rector and VanBallenberghe* illustrate best practices of climate change communication in an informal science learning environment through a polar-focused planetarium documentary show and measured the impacts of their polar-focused planetarium film in an informal education context. They summarize effective strategies for developing informal science content around climate change in polar regions.

Polar education can't be separated from climate education, for which there is also a pressing imperative. The Action for Climate Empowerment Strategy Framework for the United States (ACE Framework), published in November 2020 (Bowman & Morrison, 2020), was developed to address the requirement that every signatory nation of Paris Agreement has in place a national strategy to enable the achievement of their climate goals. The ACE Framework is intended to guide the completion of a U.S. strategic plan in time for delivery at the 26th UNFCCC Conference of the Parties in November 2021. The polar education community can benefit from the ACE Framework's recommendations, which call for climate action through increasing awareness, building local capability, enhancing information sharing, encouraging innovation and beneficial behavioral norms, improving social justice, and increasing climate literacy. Implementation of the ideas outlined in the ACE framework through a national and international strategy has great potential for increasing polar and climate education initiatives.

The editors hope that this special issue will provide education professionals, researchers, and other interested stakeholders with ideas for effectively addressing polar related topics. The papers provide examples of connections between polar science and educational standards and opportunities for engaging learners with research-based practices. Curriculum developers and teacher professional development providers will find resources that can enhance their efforts. The imperative for polar education must be tackled by both formal and informal education, and the editors are pleased to help address this need with the suite of papers contained in this special issue.

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