Polar Oceanography: Engendering Students with a Sense of Place and a Sense of Time

By Collin S. Roesler

"Sense of place" is a phrase used by social scientists to describe the deep emotional connection that people have toward a place. It can also describe a place that engenders an identity or characteristics deeply felt by people. When we have a sense of place, we naturally work hard to preserve that place. As our planet moves through the Anthropocene, experiencing not only the innate trends and cycles of nature but also the trends and cycles caused by human actions, we may notice that some characteristics that have defined our special places are changing, making parts of our world unfamiliar. It may be these observations that cause us to look up, take account, and make changes. We might also coin the phrase "a sense of time" to describe our connection to the uniqueness of our present experiences, while appreciating that comparable scenarios may have occurred in the past and recognizing the implications of our present course on future scenarios.

At present, some locations on our planet are changing at unprecedented rates, but they are visited by only a small fraction of the population. The polar regions are warming at rates far in excess of those at lower latitudes, yet changes there are least experienced firsthand by humans. Approximately 2,000 people visit Antarctica each year, and another 1,000 get close to the North Pole, accounting for about 0.0004% of the world's population. Many of those who do visit these places are repeat visitors—and the impact of these remote polar regions on those rare visitors is profound.

At Bowdoin, the small liberal arts college where I teach, I offer a comparative polar oceanography course called Poles Apart: An Exploration of Earth's High Latitudes. It is a non-laboratory course designed for students who have completed an introductory Earth science course (physical geology, environmental geology, or oceanography) and a sophomore-level Earth system science course (taught from a biogeochemical cycling perspective). Poles Apart focuses on building a foundation for understanding the factors responsible for polar ocean circulation, biogeochemical cycling, and ecosystems, while building skills in reading and synthesizing the primary literature. My course goals are to help students become familiar with the polar regions so that they care enough to both understand the underlying science and take action (develop a sense of place). We are viewing current changes from a single point in time—now. It is critical to know the past in order to understand the future that awaits (sense of time). This is my challenge.

Reading journal articles, looking at videos, and hearing a professor's personal stories of Arctic field programs do not impart the feeling of actually being there. My teaching approach is to combine readings of firsthand historical accounts with journal articles that provide an Earth systems science emphasis. Exploration readings provide not only direct observations and details but also a unique perspective on scientific discovery, while placing recent discoveries in a historical context. An additional benefit is that while the concepts ultimately covered in this course are quite complex, students engage with the material in much the same way the explorers did, discovering oceanographic principles step by step, adding layers of complexity through their readings. Each week, I pose foundational questions to the students to guide their exploration readings and to help them integrate the scientific concepts covered in class. A combination of weekly short papers, in-class student-led discussions, online student-led forums, and small working group presentations provides effective means for students to engage with and take ownership of the material.

For our study of the Arctic, students read Fridtjof Nansen's *Farthest North*. Originally published in 1897, it is a firsthand account of the three-year voyage of Nansen and his crew aboard *Fram* (1893–1896). The book is remarkable for many reasons, and I share it with my students because of its wonderful descriptions of Arctic voyage preparation, scientific discoveries, hypothesis testing and rejection, and heroic survival measures, as well as its incorporation of Inuit knowledge and Nansen's personal observations of the Arctic Ocean. After reading this single work, the insights students share in their writings and class discussions reveal a developing sense of place. Among them (students' comments in italics):

The description of the design of the Fram, *as well as the events that unfold in later chapters, clearly convey the strength of sea ice and the unrelenting forces of its motion.* The sound of the ice freezing to the hull, the groaning of the wood under pressure, the cracking of the ice as the hull breaks free, the violent tilting of the boat as it pops out of the icy claw. Sea ice becomes alive in ways not captured in studies of thermodynamics, dynamics, or stress and strain diagrams.

Observations of the waxing and waning of populations of animals above and below the ocean surface, and of plankton and benthic critters brought up in dredges, point to a seasonal rhythm of the ecosystem, at once intellectually interesting—and also deeply relevant in the crews' search for sustenance, a point never made in a journal article.

Students are always astonished to learn that up until Nansen's voyage, *it was unknown if the Arctic was composed of continents, islands, shallow seas, or a deep open basin* (Nansen, 1904). Soundings conducted through the sea ice provided unarguable evidence of the deep basin. Similarly, *measurements of temperature and salinity provided the earliest observations of the warm and salty deepwater mass originating from the North Atlantic that ultimately contributes to formation of North Atlantic Deep Water.* Meticulous documentation of ocean, ice, wind, and sky promote in students both astonishment at the beauty and variety of the Arctic and also a sense of the monotony of sea voyages and the routine necessary for collecting useful observations.

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Nansen's plan to reach the North Pole was developed after much research into the area's surface ocean currents based upon the transport of relics from prior voyages across the Arctic. He hypothesized that freezing *Fram* into the developing sea ice near the New Siberian Islands would cause the ship to drift across the pole with the ice. The not-yet-discovered process of Ekman transport foiled his plan, as the ship drifted away from the pole and the prevailing winds. Nansen's routine observations of wind and currents and his frustration at not understanding the processes at work provide students with insight into hypothesis development, the dogged determination science requires, and ultimate acceptance of a rejected hypothesis. It is also notable that Nansen, while impacted by the realities of the Coriolis force and Ekman transport, was not able to make sense of his observations. Sharing his data with one of his own students upon his return provided the foundation for the theoretical derivation of Ekman transport, a worthwhile lesson in the value of collecting quality data, keeping good notes, and publishing and sharing scientific observations and discoveries.

For our study of the Antarctic, students read Roland Huntford's account of the 1911–1912 Roald Amundson and Robert Scott race for the discovery of the South Pole in *The Last Place On Earth*. Huntford's description, based upon the explorers' diaries and other sources, provides the historical and cultural context for the voyages.[1] Aside from the engaging story of this competition and the connections to Nansen's book, the descriptions of Antarctica are astounding: relentless wind, biting cold, endless whiteness, and ever-changing snow characteristics. After the rich descriptions of Arctic sea ice, the story of endless slogging through the ice and snow of Antarctica provides a clear distinction between sea ice and the glacial ice encountered first as the ice shelf (the "barrier"), then ice falls, crevasse fields, and ice cap. Introducing these glacial features with the firsthand accounts is far more evocative than memorizing glacial vocabulary out of context, and connections to glacial flows, mass balance, buoyancy, and buttressing are more intuitive.

The final assigned book is Alfred Lansing's *Endurance: Shackleton's Incredible Voyage*, a relatively short account of Earnest Shackleton's attempt to cross Antarctica in 1914. As is generally well known, his plans were spoiled by the extreme sea ice conditions in the Weddell Sea, which trapped and crushed his boat, leaving him with no choice but to travel by foot over sea ice and later to voyage in a small boat across the Southern Ocean to find rescue. I chose this book to provide a contrast between the Arctic and Southern Oceans and sea ice zones and to show cultural contrast (i.e., two Norwegians and two British explorers). After reading the accounts of these voyages, there is little confusion about the different types of ice that comprise the cryosphere, and

[1] More recently, Huntford published *Race for the South Pole, The Expedition Diaries of Scott and Amundsen*, a side-by-side presentation of the two explorers' diaries, including a short introduction and an epilogue to provide context.

students gain an intuition into the contrasting processes that occur in a polar ocean basin versus a polar ocean surrounding a continent.

These three books afford approximately 120 pages of reading a week. The 17 daily pages lead students from the Arctic to the Antarctic and from open water to sea ice, ice shelves, and ice caps. Those interested in history and social science gain entry into, and intimate knowledge of, two decades of intense polar exploration between the rival nations of Norway and England (and the role that Nansen played in Norway's successful separation from Sweden), and of the use and rejection of native knowledge in preparing for polar exploration. Through these readings, students gain intimate knowledge of the many facets of the polar regions, and find their sense of place for two regions that most will never see.

Like a sense of place, providing students with a sense of time can similarly engender an appreciation for our place in time. As events associated with modern climate change unfold, perceiving that similar events have unfolded in the past can provide a perspective against which to evaluate them.

Across the print and online news outlets every day are items related to rising temperature, disappearing sea ice, changing polar ecosystems, slowing of the overturning circulation, glacier acceleration, and ice shelf collapse. We are likely to see a nearly ice-free summertime Arctic Ocean within our lifetimes, or the lifetimes of our children. It can be difficult to fathom the magnitude and scope of changes in the polar regions on these short time scales. Yet, the changes that we are seeing, the outcomes that will follow, have occurred in the past. We can look to the past to anticipate the future. I am often asked by students, their parents, and audience members how I remain optimistic as I help to document changing ocean conditions and ecosystem responses in my research and as I teach students about likely outcomes. My answer is simply that such changes are not unprecedented—what differs is the cause and the time scale. Over the last 200 years, humans have burned a substantial fraction of the fossil fuel reserves that took hundreds of millions of years to sequester into the geosphere, and are releasing that carbon back into the atmosphere. While Earth has seen these atmospheric conditions before, humans have not. But we are a resilient species. The characteristics that made us so efficient at exploiting resources can be used to find solutions to the challenges that society will face in a warmer world with migrating climate zones. I have faith in the critical thinking skills of my students and their desire to save the planet.

Earth system science provides tremendous opportunities for helping students make connections among Earth's atmosphere, geosphere, hydrosphere, cryosphere, and biosphere. It also demands an appreciation for geologist James Hutton's concept of "deep time" and the endless rock cycle he observed in the late 1700s that was later explained by carbon dating and plate tectonics. So, as we see rapidly changing conditions in the polar regions, it can be helpful and reassuring to look at them from a longer view. As an example, Jakobsson et al. (2007) provide a captivating description of the establishment of the Arctic Ocean's ventilating circulation patterns subsequent to the opening of Fram Strait in the Miocene (a connection to Nansen's bathymetric observations). Thus, we can begin to identify an approximate starting time for initiation of the meridional overturning circulation patterns as we know them today. Similarly, the Arctic sea ice cover that we currently know has fluctuated greatly due to changes in solar radiation that result from orbital variations. Understanding the forces driving sea ice fluctuations as well as the resultant impacts by no means negates what we are currently observing, but does provide some context for understanding how it may play out, the predictable outcomes, and also the uncertainties and unpredictable outcomes. Thus, there is some comfort in knowing the knowns and knowing the unknowns.

One of my former PhD students, now a young researcher studying ice shelf collapse, asked me, as he was deciding whether or not to pursue graduate work focused on the cryosphere: "Am I really going to dedicate my career to a topic that is literally melting away beneath my feet?" "Yes," I replied, "and that is why it is critical that you do so."

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