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Engaging Students in Inquiry Using Authentic Ocean Data

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Abstract

To engage in inquiry, students must gain experience in obtaining, analyzing, and interpreting data, yet traditional science instruction has not given students adequate opportunities to truly engage in these practices. Freely available oceanic data sets include sea surface temperature (SST), bathymetry, chlorophyll, pollution, sea ice, salinity, and tracks of animals. Utilizing these and other authentic data sets can make learning experiences more powerful for learners, giving students the opportunity to gain contextual understandings of the applications of science. This article, based on a presentation at International Week 2017, discusses the international importance of ocean literacy, and ways in which employing authentic ocean data can support students' development of scientific practices and increase their ocean literacy.

Keywords:
Ocean literacy
Inquiry
Authentic data
Science and engineering practices

1 Introduction

This article, based on a presentation given at *International Week 2017*, discusses the importance of promoting the use of science practices, and how integrating authentic ocean data into science classrooms can support students in this endeavour and ultimately promote ocean literacy.

2 Science Practices for the 21st Century

Addressing today's 21st Century issues, including climate change, energy independence, freshwater availability, and disease, will require citizens capable of strategic thinking and evidence-based problem solving. These skills are critical components of the international movement to improve workforces highly trained in science, technology, engineering, and mathematics (STEM) disciplines. Yet, solving 21st Century problems will require both education in the STEM disciplines, as well as creativity, in order to address these issues in meaningful ways. International collaboration will be critical (Heilbronner, 2014).

There has been a shift in how experts believe science should be taught, in order to produce thinkers ready to tackle these global problems. Osborne (2014) contends that students must engage in science practices themselves to truly understand how science is practiced professionally and knowledge advanced. Traditionally, the way students learn science in classrooms is quite different from how scientists work and in fact can misrepresent scientific practices (Hodson, 1998; Wong & Hodson, 2008). Recently, science educators in the United States have adopted a new set of standards, the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013). These standards emphasize not only scientific content, but also *"crosscutting concepts,"* big ideas that apply to diverse disciplines of science, e.g., patterns and structure and function. Additionally, the NGSS have a strong emphasis on eight science and engineering practices (Table 1), explaining that students must employ

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these practices to achieve the performance expectations at their grade levels. These practices mimic what scientists actually do (Osborne, 2014). By truly using scientific practices, students will learn concepts more deeply and be more motivated to learn (Minner, Levy, & Century, 2009).

	The NGSS Science and Engineering Practices
1	Asking questions (for science) and defining problems (for engineering)
2	Developing and using models
3	Planning and carrying out investigations
4	Analyzing and interpreting data
5	Using mathematics and computational thinking
6	Constructing explanations (for science) and designing solutions (for engineering)
7	Engaging in argument from evidence
8	Obtaining, evaluating, and communicating information

Table 1: The NGSS Science and Engineering Practices

3 Ocean Literacy

The ocean is Earth's most significant feature, covering more than 70% of the planet's surface and representing most of the available living space for the biosphere. It contains Earth's highest mountains, widest plains, and deepest, darkest canyons. Yet, studies in different countries indicate that people are largely ocean illiterate (Ballantyne, 2004; Boubonari, Markos, & Kevrekidis, 2013; Brody, 1996; Ocean Project, 2009; Payne & Zimmerman, 2010; Steel, 2006). The definition of ocean literacy is *"an understanding of the ocean's influence on you, and your influence on the ocean"* (Carley et al., 2013, n.p.)

- understands the essential principles and fundamental concepts about the functioning of the ocean;
- can communicate about the ocean in a meaningful way; and
- is able to make informed and responsible decisions regarding the ocean and its resources

From a cognitive standpoint, the definition and components are vague, but represent the current working definition of ocean literacy used in the marine education field. The term "ocean literacy" was first coined in about 2004, as a result of the work of a group of marine educators, ocean scientists, and others seeking to create a framework of ideas about the ocean with which educated people should be familiar. The team decided upon seven Essential Principles of Ocean Sciences (Table 2), which overarch 45 fundamental concepts. The working group has also developed a scope and sequence of these ideas to illustrate what students should know at different grade and developmental levels (Schoedinger, Tran, & Whitley, 2010). Because the ocean is such an integral part of the Earth system, one cannot be considered scientifically literate if they are not ocean literate (Strang, deCharon, & Schoedinger, 2007).

	The Essential Principles of Ocean Literacy
1	The Earth has one big ocean with many features.
2	The ocean and life in the ocean shape the features of the Earth.
3	The ocean is a major influence on weather and climate.
4	The ocean makes Earth habitable.
5	The ocean supports a great diversity of life and ecosystems.
6	The ocean and humans are inextricably interconnected.
7	The ocean is largely unexplored.

Table 2: The Essential Principles of Ocean Literacy

As the world shares one global ocean, ocean literacy is becoming an internationally recognized issue. For instance, in 2013, the European Union, United States, and Canada signed the Galway Statement on Atlantic Research Cooperation, which focused on a vision for ocean science cooperation, but also stated an intention to promote ocean literacy. The European Union's Horizon 2020 program includes several initiatives to improve ocean literacy, including the Sea Change Project and ResponSEAble. Most of these programs are aimed at public ocean literacy, but including ocean sciences in school curricula and assessments will be a critical strategy for improving overall ocean literacy (Tran, Payne, & Whitley, 2010). It is also notable that youth, ages 12-17, are more likely to care about the ocean and related environmental issues than adults, and can also affect adults' opinions (Ocean Project, 2009, p. 2).

Unfortunately, including environmental education topics such as the ocean in school curriculum has been a struggle since the environmental movement's beginnings in 1960s. These topics are considered an "add-on" to the curriculum, as has happened to the ocean sciences (Lambert, 2006; Walker, Coble, & Larkin, 2000). Gruenewald and Manteaw (2007), identify issues that are quite pertinent to marine education, noting that environmental education is often *"marginalised, misunderstood ... and in many places totally neglected"* (p. 173). One way to combat this issue is by using the environment as an integrating context (EIC) for learning. Proponents of this argument believe that teaching students science and other subjects using environmental education will lead to greater student engagement and performance (Lieberman & Hoody, 1998). The ocean sciences are inherently interdisciplinary—it is common for marine scientists to study across traditional scientific disciplines, and to work closely with technologists and engineers. Therefore, the ocean can be used as an EIC. A study by Lambert (2006) found that marine science can be a useful model for integrated science instruction, leading to increased student performance. But other than learning science content, how can we support students in developing their use of scientific practices?

4 Using Authentic Ocean Data

One approach to engaging students in science and engineering practices is to integrate authentic data into the classroom. Traditionally, primary and secondary learners have been asked to analyse and interpret facsimile data sets generally created for student study. The data are typically easily analysed, allowing students to draw straightforward conclusions. Students are frequently not *"doing science"* (Hodson, 2006), but instead engaging in laboratory exercises in which they replicate known procedures and findings, or confirm content that they have already been taught.

Thanks to advances in scientific observation and communication, Earth and space are under constant monitoring, and the data are freely available online. In marine science, available data sets include bathymetry, sea surface temperature (SST), sea ice, meteorological information like air temperatures and wind speeds, and animal locations. These data can be accessed online through EU and American government websites and those of other agencies, therefore representing a relatively easy way for students to work with authentic data, and meet performance expectations of the NGSS Standards, using science and engineering practices as they engage deeply with content (Marrero & Woodruff, 2016; Marrero, Gunning, & Woodruff, 2015). When students analyse authentic data, learning experiences become more powerful (Ucar & Trundle, 2011; Adams, 2011); students make deeper connections to the content. Learners also better understand the importance of science in the real world, the applications of science practices and principles (Chinn & Malhotra, 2002; Doering & Velestsianos, 2007; Krumhansl et al., 2013; Lee & Butler, 2003). By working more frequently with real-world data, students may be better prepared to address 21st century issues, which will require these types of problem solving skills.

Global climate change, and resultant rising sea levels, coastal flooding, ocean acidification and other related issues will continue to be of great concern to the scientific community in the next few decades. By accessing, analyzing, and interpreting oceanic data sets, students can better understand these issues, providing them with foundational knowledge that may ultimately help address the problems. For example, students can access online data from the European Environmental Agency (EEA), and examine sea surface temperature (SST) anomalies over the past 150 years for the major European seas and the global ocean. SST anomalies represent the differences between yearly SSTs and some average, in this case the 1993-2012 average (Figure 1).

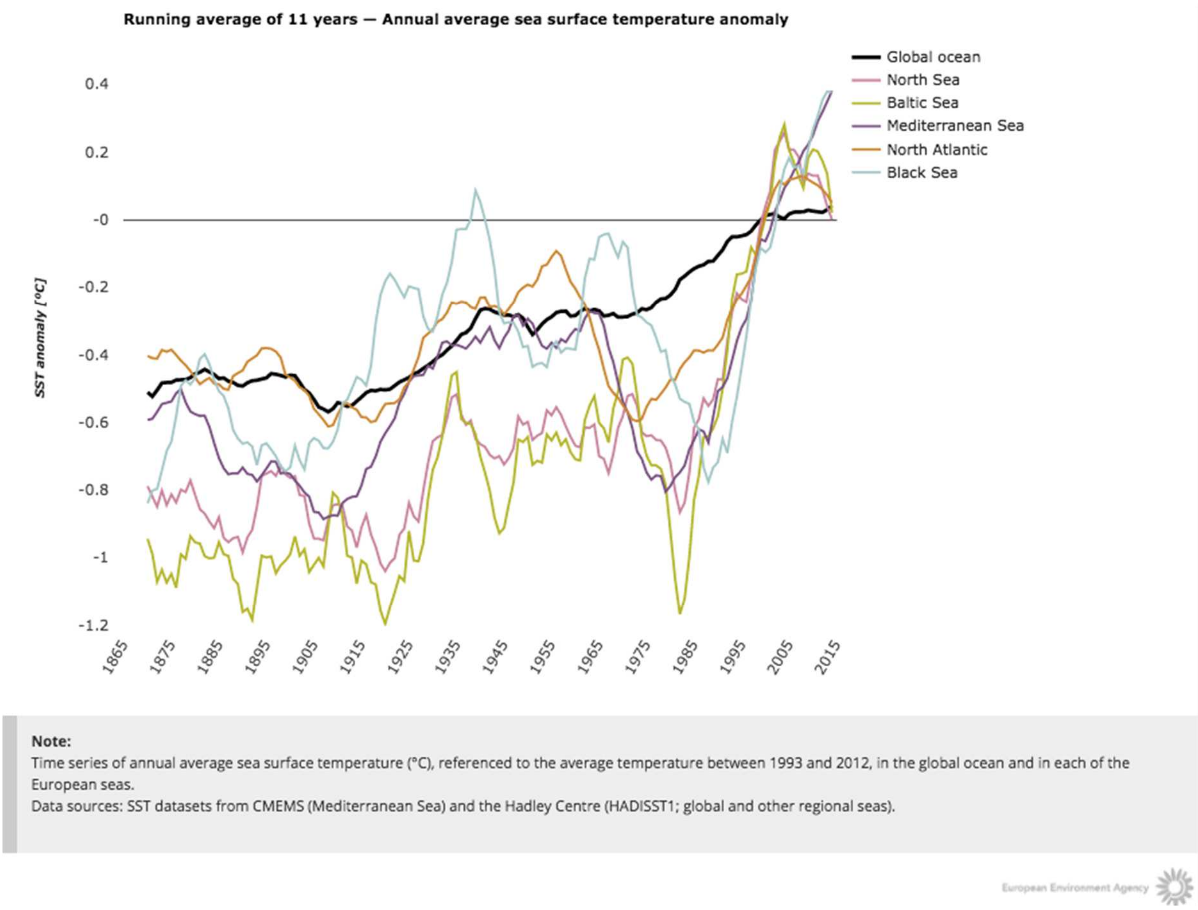

Fig. 1: Annual Average SST Anomaly, Credit EEA

Students could first perform their own initial analysis of a graph like this one, using NGSS science and engineering practices such as *Analyzing and Interpreting Data* and *Using Mathematics and Computational Thinking*. Teachers could then ask students to consider this graph more deeply—what do these data mean? What is a trend? Which seas are warming faster/slower than others? Students can then compare these data to other available data sets, e.g., global SST, hurricane activity, air temperatures, in order to engage in practices such as *Constructing Explanations* and *Engaging in Argument from Evidence.* At the same time, with guidance from their teachers, students could develop their ocean literacy, for instance, exploring the role of the ocean in weather and climate (Ocean Literacy Essential Principle 3). Thus, engaging with authentic ocean data could help students to strengthen both their scientific abilities as well as their ocean literacy.

5 Conclusion

More studies are certainly needed on this approach, including how teachers can successfully integrate authentic data and how to make these activities accessible for diverse levels of learners. However, this approach represents a promising avenue for improving both the use of science and engineering practices as well as ocean literacy.

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