AN ABSTRACT OF THE THESIS OF

Danielle Miller for the degree of Master of Science in Marine Resource Management presented on June 5, 2019.

Title: The Data Stream: Assessing the Flow of Real Time Marine Science Data from Research Vessel to the Classroom.

Abstract approved: ____

Tracy D. Crews

Today's technology-based society makes information more accessible than ever, in turn creating a growing demand for a workforce that has the skills necessary to utilize data. Contributing to this influx of data is Oregon State University (OSU), who was selected to guide the design and construction process of three Regional Class Research Vessels (RCRVs). These vessels will be capable of producing enormous amounts of crucial, real-time oceanographic data. As part of the RCRV Education and Outreach team effort, this two-phase project seeks to support data literacy by streamlining the Data Stream, or the flow of data from researcher to educator to student. Phase one of the project utilized a literature review; 32 interviews with marine researchers, educators, and professional development providers; 8 years of professional development surveys; a data-portal review with classroom; and data-portal surveys with classroom teachers to identify key challenges faced when utilizing research data in outreach and learning activities. These methods result in informed recommendations that can aid in facilitating the transfer of data between researcher and teachers/students.

Phase two of this project assessed how data-focused experiential learning impacted student data literacy, attitudes toward science, and beliefs about science. Two high school biology classes participated in hands-on, data-focused learning activities, whereas two other classes participated in passive learning activities. The lessons utilized authentic oceanographic data that were collected off the Oregon Coast by researchers. Over the course of three days, students were introduced to the concepts of oceanography and collection of marine science data, how to understand and critically evaluate sets of data, and were encouraged to reflect on and discuss why understanding ocean data is an important skill in today's world. Surprisingly, the passive learning group (PLG) showed significant changes in all three variables (data literacy, attitudes toward science, beliefs about science), whereas the experiential learning group (ELG) did not have any significant change. This, however, does not negate a connection between positive impacts and data-focused experiential learning, but instead highlights additional challenges that need to be addressed when attempting to foster data literacy in students.

The Data Stream: Assessing the Flow of Real Time Marine Science Data from Research Vessel to the Classroom.

By

Danielle Miller

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Presented June 5, 2019
Commencement June 2020

Master of Science thesis of Danielle Miller presented on June 5, 2019

APPROVED:

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Dean of the College of Earth, Ocean, and Atmospheric Sciences

Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Danielle Miller, Author

ACKNOWLEDGEMENTS

This research would not have been possible without the support, guidance, and contributions of many individuals. I am grateful for the opportunity to pursue this research through funding from the National Science Foundation via the Regional Class Regional Vessel (RCRV) project, and additional support from Oregon Sea Grant. To both past and present members of the RCRV team, I am indebted to you for this opportunity. I want to extend my sincerest appreciation to the researchers, educators, professional development providers, and students that participated in this research, as well as the Lincoln County School District. Thank you all for your valuable insight and feedback.

Words cannot adequately express my gratitude to my committee. My advisor, Tracy Crews, has not only shown me how to be a stronger scientist and writer, but a stronger woman as well. Thank you for guiding me through the past two years, and for providing me with so many experiences beyond the office. To Mark Needham, thank you for helping me overcome my fear of statistical analysis, and for always lending an ear. To Craig Risien, thank you for reminding me of the bigger picture, and making me feel like I always had someone in my corner.

I can’t imagine my time in graduate school without the laughter and support of my fellow MRMers. To Tori, Bri, Moses, Katy, Emily, Katie, Dom, Anja, and Jenn, I can’t wait to see where your new adventures take you. To my family, thank you for your never-ending support and love. To my friends, thank you for being there when I needed you the most. To Cody, thank you for filling my days with laughter, and for tolerating the sound of the coffee maker at 2am. Finally, thank you to Sam and Colt, who kept me company through the long nights of writing and deserve extra dog treats for it.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

Chapter 1

Introduction, Background, and Objectives

1.1 Workforce Needs

In today’s connected world, data permeates almost every aspect of our lives, whether they are coming from a navigation system, social media, or cellphones. The availability of data in the United States is rapidly growing, and with it, the demand for a workforce that is prepared to handle the data *(Building Global Interest in Data Literacy: A Dialogue Workshop Report,* 2016*)*. The ability to make sense of data is a considered to be a critical skill by many employers, and having that skill can provide access to significant career opportunities, given that jobs requiring data science skills are anticipated to grow 28% by the year 2020 (Markow, Braganza, Taska, Miller, & Hughes, 2017). Despite having abundant access to data, many Americans continue to struggle with basic scientific concepts and there is a growing concern that the K-12 system may not be adequately preparing students with the skills they need to join a changing workforce (National Academy of Sciences, 2007). High school students are a particular concern, as they struggle with locating and evaluating data, as well as recognizing credible and meaningful connections (Brem, Russell, & Weems, 2001; Schmar-Dobler, 2003).

1.2 RCRV: A Future Source of Data

The Regional Class Research Vessel (RCRV) project at Oregon State University (OSU) is poised to become a critical source of real-time oceanographic data. In 2013, OSU was selected by the National Science Foundation (NSF) as the lead institution on a project to oversee the design and construction of three new RCRVs. These next-generation vessels will have more modern technological capabilities than previous research vessels, including "datapresence," which refers to the ability to live-stream data from a suite of shipboard instruments, something not currently available in the existing fleet. This project provides a unique opportunity for the RCRV team to help foster communication and collaboration among researchers, teachers, and students in an effort to stimulate data literacy and support the future workforce.

1.3 The Data Stream

Data literacy (DL) is considered to be the ability to understand data, which includes accurately evaluating graphs and figures, identifying trends, making data-supported conclusions, and recognizing corrupt data (Carlson, Fosmire, Miller, & Nelson, 2011). As part of the RCRV education and outreach plan, a two-phase research project was conducted to assess the challenges and best practices of utilizing real-time marine science data in education and outreach efforts. Phase one focused on identifying the challenges and solutions related to the transfer of data from marine researcher to teacher to student, referred to as “The Data Stream.”

At each point in the Data Stream (Figure 1.1), various stakeholder groups have specific roles in utilizing data, as well as their own set of challenges utilizing data for educational purposes. Researchers first must collect, analyze, and then communicate the data, supplying the next point in the stream (teachers) with data to use in their classrooms. However, researchers can struggle with a variety of challenges concerning communication of data. There is evidence that a disconnect exists between researchers’ perceptions of effective outreach and what stakeholders consider to be effective outreach. For example, in a study examining how researchers view the outreach process, the majority of them identified key issues preventing effective engagement, including “the public’s ignorance” and “the public’s disinterest toward science” (Ecklund et al., 2012).

This disconnect is further highlighted in another study of researchers focusing on their communication efforts, where only 12% of participants indicated that successful engagement with the public involves listening and attempting to understand their views (The Royal Society, 2006). Researchers experience frustration with a public they perceive as disinterested in their work, while the public is frustrated by researchers they perceive as being detached. Identifying barriers that researchers face, as well as the best ways to reach them is critical in building researcher understanding of how to bridge this disconnect.

Figure 1.1: The Data Stream (Oceanographers unload a CTD in September 2018, an educator explains fishing gear to a class in 2017, students examine plankton in 2017, a science party waits to leave port in September 2018).

The next step in the data stream is educators, who receive the data from researchers and then must integrate these data into their classroom activities. Teachers also experience many challenges in the flow of data to their students that must be addressed. It can be challenging for teachers to provide students with the data literacy and science literacy skills they require, especially when teachers do not feel confident in their own data literacy skills (Carlson et al., 2011; Johnson, Adams-Becker, Estrada, and Freeman, 2015). Teachers also indicate that internal factors within their schools, such as support from administrators and personal learning networks, play critical roles in shaping their teaching practices (Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012). Teachers often face barriers to using technology due to skill levels and expertise, as well as problems within the school regarding availability of technology, internet, and instructional time (Bodzin, Klein, & Weaver, 2010; Jelinek, 1998).

The third connection in the data stream is students, who must connect with, understand, and effectively utilize the data. Some of these students may join the much-needed data literate workforce, eventually closing the loop as they become suppliers of data themselves.

1.4 Study Purpose

The research in this thesis seeks to identify the challenges and solutions that will best support an unimpeded data stream, where data flows from stakeholder to stakeholder, ultimately in support of an engaged and data-literate society. This objective was reflected in the design of phase one, which was a multi-pronged approach to answer the following goals: (a) identify the current status of data-use by researchers via outreach, and teachers in their classrooms (b) identify the barriers each group faces, (c) identify ways of addressing barriers.

1.5 Study Design: A Two-Phase Approach

This research was conducted in two phases, the first phase identified the challenges and best practices for facilitating the transfer of data from researcher to teacher to students. The second phase resulted in the development and evaluation of a data-focused, experiential learning module on high school science students. Although detailed methods are included in subsequent chapters, a brief overview follows.

In phase one, a literature review was conducted followed by a review of 8 years-worth of data-focused workshop surveys. Thirty-two interviews were then conducted with researchers, teachers, and professional development providers (people or programs that design, implement and evaluate informal learning opportunities for professionals) to gain important insight from each stakeholder group. In addition, an evaluation of data-portals (websites specifically designed to deliver data) was conducted, followed by a teacher evaluation of a subset of online data-portals by teachers participating in an educator workshop.

The results of phase one highlighted key barriers faced by both researchers and teachers when attempting to utilize data in education and outreach, including a lack of knowledge, a lack of support, and a lack of time. Utilizing information pulled from the various data collection sources, phase one concludes with recommendations to provide the resources necessary for remedying the identified barriers. Additionally, the results highlighted a need for deeper exploration into the implementation of data-focused learning in the classroom. Using recommendations from teachers surrounding what defines “good data” for classroom use, phase one then informed the design and implementation of phase two.

In phase two, a study on data-focused learning was designed and implemented with four high school biology classes located in Lincoln County School District, Oregon. For this experiment two classes were assigned to an experiential learning group (ELG), and the other two were assigned to a passive learning group (PLG). Experiential learning activities have been shown to increase student perception of value, enjoyment, performance on assignments, and enthusiasm (Hamer, 2000). Utilizing experiential learning activities can also assist in increasing the amount of information retained by students, as students feel more connected with the course material and can also result in students being more engaged in the classroom (Association for Experiential Education, n.d.; Carver, 1996; Guest, Lotze, & Wallace, 2015; Jelinek, 1998; Van Eynde & Spencer, 1988).

Both groups received the same introduction to oceanography and data lesson on day 1 (Figure 1.2). On day 2, the ELG participated in a hands-on activity that required them to analyze, graph, interpret, and communicate, whereas the PLG received a lecture on different types of data collection methods. On the final day, both groups participated in a discussion on the relevance and importance of oceanography and data to their daily lives. Students were surveyed using pre (one week before instruction), post (the last day of instruction), and post-post (six weeks after instruction) surveys to evaluate changes in their data literacy, as well as their attitudes and beliefs about science. Positive attitudes and beliefs about science mean that students understand and appreciate the role of science in the world around them, value the contributions of science to their lives and society, and can contribute to higher levels of engagement in the classroom (Schiepe-Tiska et al., 2016; Nolen, 2003). Following classroom implementation and teacher feedback, the module was revised and is presented as part of this thesis in its final form.

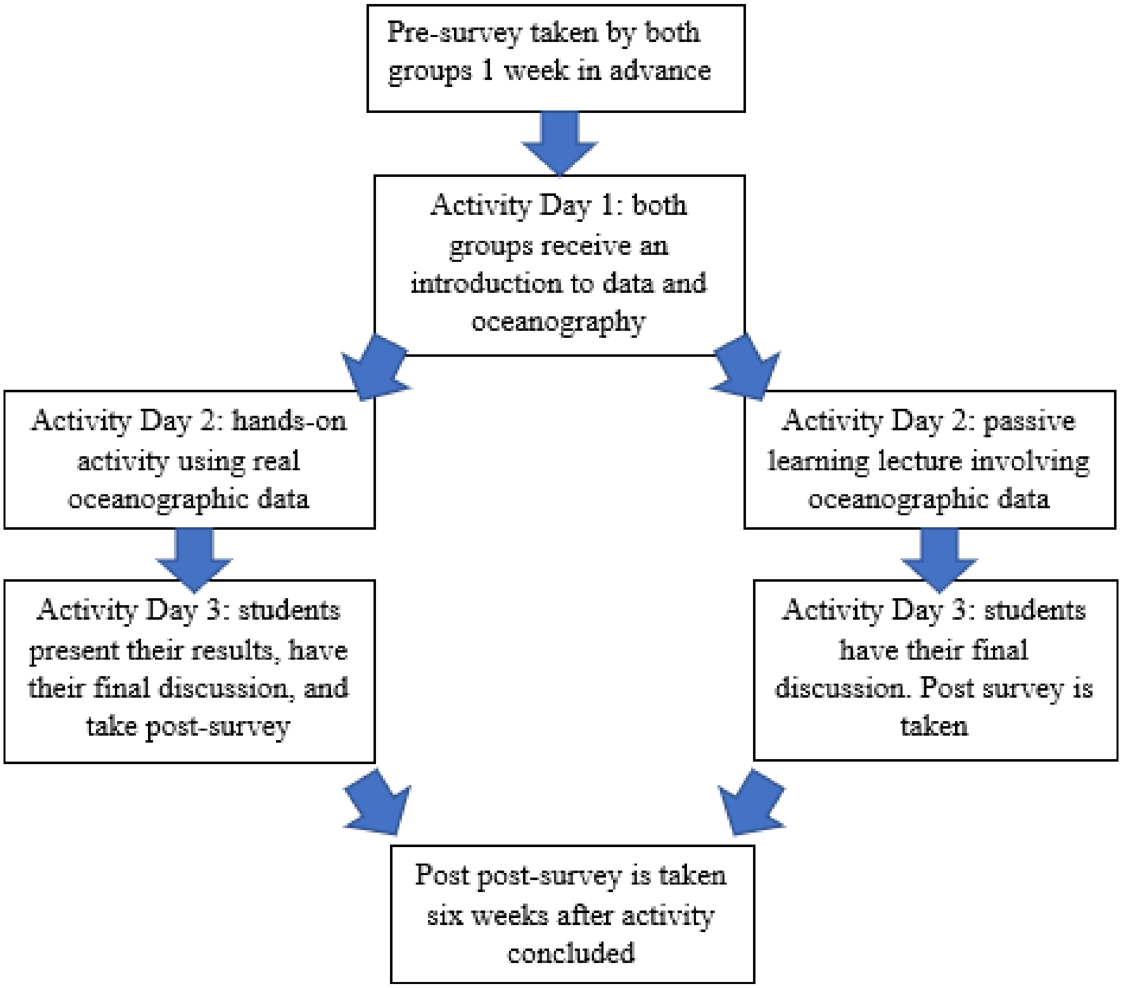

Figure 1.2: Experimental design of Phase Two

1.6 Thesis Outline

This thesis examines the flow of marine science data from a research vessel to the classroom. Phase one is described in detail (Chapter 2), whereas Chapter 3 addresses phase two, which involved the creation and implementation of a data-focused experiential learning module for high school science classrooms. The impacts of this module on each student's data literacy, attitudes toward science, and beliefs about science assessed in Chapter 4; and are followed by the conclusions in Chapter 5, that discuss overall findings, the challenges of the study, and future opportunities for research on this topic.

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Chapter 2

Assessing Needs, Opportunities, and Issues Related to Data Use in Education

2.1 Introduction

Education and outreach concerning research is vital in creating an informed general public. Our nation often struggles with basic science concepts, and our overall science literacy is generally classified as poor (Bishop, Thomas, Wood, & Gwon, 2010). This is an important issue, as the United States has a growing demand for a workforce that is able to address science concepts and confidently work with data *(Building Global Interest in Data Literacy: A Dialogue Workshop Report*, 2016*).* Additionally, there are growing concerns that K-12 education is not adequately preparing students to become the scientific leaders and problem solvers this future workforce requires (National Academy of Sciences, 2007).

2.2 Scientific and Data Literacy: Room for Growth

2.2.1 Scientific Literacy

Given that issues such as climate change, marine debris, and habitat destruction are receiving considerable attention, there is ample opportunity to make science instruction both relevant and meaningful to students (Chamany et al., 2008). As students advance from primary to secondary education, many lose interest in science and cease seeing it as a viable option for their future or associating it with their success (Chistidou, 2011). Subsequently, although the total number of bachelor's degrees awarded annually in the United States has nearly tripled over the past 40 years, STEM degrees have not (Beering et al., 2010). Graduation statistics reveal that in 2006, the relative percentages of students earning degrees in nearly all STEM fields were at, or below, previous levels (Beering et al., 2010).

In 2012, the President's Council of Advisors on Science and Technology found that if the United States was to retain its historical preeminence in science and technology, then it would need to increase the number of undergraduates with STEM degrees by 34% above the current annual rate and produce approximately 1 million more STEM professionals (Olson & Riordan, 2012). Being engaged in science in high school is generally necessary to successfully complete science courses in college, and studying science in college is generally necessary to pursue career in science (Sheldrake, Mujtaba, & Reiss, 2017). Additionally, research shows that a large portion of students who concentrate in STEM make that choice during high school (Maltese & Tai, 2011). It is clear that high school is a critical time for students to be engaged in science so that they may pursue STEM in both their post-secondary education and careers. To be ultimately successfully in their pursuit, students must also build a strong foundation in their understanding of data as well.

2.2.2 Data Literacy

Data literacy (DL) often refers to an understanding of what a set of data mean, and includes reading graphs and figures accurately, pulling supportable conclusions from data trends, and recognizing when data may be corrupt (Carlson et al., 2011). Data Literacy is promoted by Next Generation Science Standards (NGSS) Practices, including the *Analyzing and Interpreting Data* practice, and is reflected in many of Common Core's Math, English Language Arts (ELA), Social Studies, and Science and Technical Subjects standards ("Read the Standards | Common

Core State Standards Initiative”; “Read the Standards | Next Generation Science Standards”). Despite this, students often perceive their abilities over-confidently, ranking their perceived skills (i.e., self-assessed knowledge) as much more proficient than their demonstrated skills (i.e., factual knowledge) (Maughan, 2001).

In a world that is heavily saturated with information, it is important to equip students with these skills as part of their overarching scientific literacy skill set (Kjelvik & Schultheis, 2019). With such abundance of data in existence, it is critical that data literacy be recognized as a necessary civic skill, for the benefit of not only students, but also for employers and society as a whole (Swan et al., 2009). The demand for a data-literate workforce is increasing, to support the growing availability of STEM careers, an increase in data, and the need for data-driven decision-making (Johnson, 2018; Janssen, van der Voort, & Wahyudi, 2017; Provost & Fawcett, 2013).

2.3 The RCRV Project: A New Source of Data

2.3.1 The Technology

Oregon State University (OSU) is set to become another producer of critical data. In 2013, OSU was selected by the National Science Foundation (NSF) as the lead institution on a project to oversee the design and construction of three new Regional Class Research Vessels (RCRVs). These next-generation ocean going research ships will have more advanced technological capabilities than previous research vessels, that will allow both scientists and educators access to crucial real-time oceanographic data. The RCRVs are designed to be quieter and more environmentally conscious, and will greatly expand the capacity for marine science research. In 2022, OSU will assume control over the first RCRV, and operate on the West Coast as part of the University-Oceanographic Laboratory System (UNOLS). UNOLS is an organization composed of 59 academic institutions and National Laboratories involved in oceanographic research, and is responsible for scheduling a fleet of 18-vessels and 14 research facilities. The R/V *Taani* will replace the aging OSU research vessel *Oceanus*, and provide OSU with updated technology and safety precautions. For example, onboard instrumentation such as multi-beam sonar and dynamic positioning systems, advanced anti-roll systems, combined with energy efficiency to allow for a smoother, safer, and more efficient research cruise.

The current UNOLS fleet is aging and suffers from a variety of associated issues that impact the effectiveness and efficiency of scientific research, including dated technology. As a result, nine vessels are scheduled to be retired by 2022. The new RCRVs will increase the efficiency in the fleet and the ability to address stakeholder needs.

The term datapresence refers to the capability of live-streaming data from a suite of shipboard instruments, something not currently available in the existing fleet. In older vessels, data are often collected, stored, taken back to a shore-based lab, then analyzed. The ability to beam data to shore with little turnaround time allows for land-based research crews to actively participate in real-time, and will allow other stakeholders unique access to research at sea. Real-time data (RTD) are not to be confused with “near real-time data,” which generally means data receive more quality control, and take longer to become available to those interested. Telepresence, or the ability to transfer live video feeds, is another technology currently utilized by some research vessels and programs to involve shore-based researchers, communicate with classrooms, and engage the general public.

The OSU RCRV project website specifically describes datapresence as: “a tool to facilitate virtual research at sea while providing an interdisciplinary approach to ocean science research, one that enhances observational, experimental and analytical capabilities. Implementing the RCRV class as a shore-accessible continuous data collection system will link scientists everywhere to quality real-time data and promote unprecedented shore-based expertise and participation in sea going operations."

2.3.2 Opportunities for Communication and Collaboration

The RCRV project provides a unique opportunity to foster communication and collaboration among researchers, teachers, and students in an effort to build both scientific and data literacy. These skills are critical in today's data-saturated world, where the general public has ever-increasing access to data. As part of the RCRV education and outreach team, a two-phase research project was conducted to assess the challenges and best practices of utilizing real-time marine science data in education and outreach efforts. The first phase of this project focused on how to effectively streamline the transfer of data from marine researcher to teacher to student, referred to here as "The Data Stream."

Although there is importance in fostering and supporting science and data literacy skills at the primary and post-secondary level, this research focused on middle and secondary education, as this is the age when skills should be solidified as students prepare for the next phase of their education. High schoolers in particular struggle to find, discern credibility, critically evaluate, and make meaningful connections with data (Brem, Russell, & Weems, 2001; Schmar-Dobler, 2003). Leaving skill development to the post-secondary environment does not ensure that citizens are sufficiently skilled to participate fully in 21st century life, in workplaces, or in their personal life contexts (Julien & Barker, 2009).

2.4 Background and Objectives

In today’s increasingly connected world, data is integral to most aspects of our daily lives, whether you are a scientist or not. Waking up to check a social media feed, the weather, or a traffic report for your morning commute are all actions driven by data. The availability of data in the United States is growing rapidly, as is the demand for a society that has the necessary skills to interpret and evaluate data (Building Global Interest in Data Literacy: A Dialogue Workshop Report, 2016). This ability to make sense of data is a desirable skill by many employers, and jobs requiring data interpretation skills are anticipated to grow 28% by 2020 (Markow, Braganza, Taska, Miller, & Hughes, 2017).

In Oregon, there is also a boom in STEM career opportunities. Over the period of 2017 to 2027, 93% of Oregon STEM jobs are projected to increase by 15% (“10-year Occupational Projections”, 2018). The State of Oregon Employment Department forecasts more than 400,000 job openings, mainly due to both growth in the field as well as the need to replace workers who leave the field. Of these jobs, nearly 70% will require some sort of post-secondary education and 50% require a bachelor’s degree (“10-year Occupational Projections”, 2018). Despite this growth, there is concern that Oregon’s workforce is not adequately being prepared to fill these openings. The future workforce, particularly Oregon’s high school students, need to have strong foundations in scientific literacy and data literacy to become the problem solvers and decision makers of the future. This is especially important as we continue to gain increasing access to data at the touch of a button.

2.4.1 Teachers and Data

While teachers are expected to provide the necessary skills for students to be both science literate and data literate, it can be especially challenging for them when they don’t feel confident in their own foundation in data literacy (Carlson, Fosmire, Mandinach & Gummer, 2013; Johnson, Adams Becker, Estrada, and Freeman, 2015). Teachers also report that internal factors within the school, such as support from administrators and personal learning networks, played critical roles in shaping their teaching practices (Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012). Teachers often face strong barriers to using technology due to existing attitudes toward technology, as well as current levels of knowledge and skills. Teachers also face problems within the school regarding availability of technology, internet and instructional time (Bodzin, Klein, & Weaver, 2010; Jelinek, 1998). Providing activities based on canned data could provide teachers with the materials they need to implement, with the option of incorporating real time data into instruction, when the comfort level is reached or there is better access to technology. Teachers also identified barriers relating to the time commitment required to fully delve into complex data sets, which becomes particularly intimidating when students have little prior experience with data analysis (Konold et al., 2000).

2.4.2 Researchers and Outreach

To become scientific leaders and solve complex problems facing them today, students will need high levels of scientific literacy (National Academy of Sciences, 2007). In an effort to support this, more pressure is being put on researchers to engage in scientific education at the K-12 level (Komoroske et al., 2015). This increased emphasis is exemplified by the National Science Foundation’s addition of Broader Impacts requirements. These requirements call for research and activities that benefit STEM education, the greater scientific community, and society at large (National Science Foundation, 2011).

Resulting from the call for more active engagement of researchers are programs such as “Scientist in the Classroom,” which aim to provide students with expertise and inspiration, which in turn spark interest in science and science-related careers (Komoroske et al., 2015). The Center for Advancing Research Impact in Society (ARIS) was formed in 2018, and is working with scientists and other stakeholders to build capacity, foster relationships, and provide resources to help scientists engage with the public. Outreach poses promising benefits for both researcher and students, especially in an era of scientific distrust, critical environmental issues, and declining funding rates. As of 2017, 44% of research was publicly funded, so it seems that building public support is vital (Mervis, 2017; Varner, 2014).

Half of all academic scientists are participating in some sort of outreach, but only five percent of the most active public scientists are responsible for half of all the outreach (Ecklund, James, & Lincoln, 2012). If the benefits are so promising, then why are not all scientists participating in outreach activities? A variety of challenges have been documented, with most stemming from the researcher perception of outreach itself. In a sample of researchers who described “the public” as one of the main challenges, 70 percent expressed a perception of public ignorance, while 30 percent called out the public’s disinterest in science as a barrier to effective outreach (Ecklund et al., 2012). Ironically, when discussing outreach and trying to engage the public, only 12% of scientists in a large survey responded that *engagement* meant listening or attempting to understand the views of the public (The Royal Society, 2006). These results indicate a general disconnect between scientists and the public.

2.4.3 Professional Development Opportunities

Problems with data discrepancy, deficient data literacy, and lack of support or enthusiasm have the potential to be remedied by providing additional resources and professional development (PD). These could include courses that focus efforts on strategies for facilitating change in teacher's attitudes and improve self-efficacy with data use (Ertmer et al., 2012). Generally, PD should have a main idea that teachers should learn (increasing DL) and a strategy for helping teachers enact that idea within their own ongoing systems of practice (sharing resources, communication, etc.). Without related training, the potential found in the use of authentic data may not be apparent to teachers. Therefore, in addition to educational resources, teachers will require training to adequately prepare them to teach with data, and develop confidence necessary to interact with digital data (Claro et al., 2018). Workshops should be offered to support instructors as they incorporate data literacy into their curricula (Wilson, 2013). Additionally, programs like field stations and marine laboratories can facilitate direct communication between the science community and educators (Struminger et al., 2018), providing opportunities for scientists to share their data and the stories behind their research with students and the public (Schultheis and Kjelvik, 2015). Follow-up support post-workshop should be incorporate to strengthen the knowledge gained at a workshop for long term retainment, and to encourage continuous learning beyond the workshop. Follow-up support is not the introduction of new information; it is the reinforcement of information provided at the professional development event (CDC, n.d.).

In addition to PD, more educational curriculum materials could be designed and offered to support DL. Curriculum materials for Grades K–12 that are intended to promote teacher learning in addition to student learning have come to be called *educative curriculum materials*

(Davis & Krajcik, 2005). Teachers read, understand, and adopt ideas from the subject matter supported in the curriculum materials that they are using, in addition to learning subject matter from the discussion of students’ ideas. Usually, support for subject matter knowledge refers to learning the facts and concepts within a subject; but it could and should also include the disciplinary practices within the subject area (Davis & Krajcik, 2005).

2.4.4 Onboard Outreach and Communication

As technology advances, so do education and outreach opportunities aboard research vessels. In many of the existing research vessel programs in existence today, researchers and outreach teams should consider 1) live-interactions with stakeholders; 2) blog posts and social media; 3) providing stakeholders with experiential learning (Raineault, Flanders, & Bowman, 2018). For live-interactions with stakeholders, this refers to providing opportunities for stakeholders to witness the research process firsthand, often represented with video feeds delivered via telepresence or a researcher skyping into a classroom. Examples of interactions include videos of day to day actions on a research vessel, or with live streams of research activities such as ROV dives. Interaction can also take form in the use of social media, to communicate updates about a coming project, highlight researchers, and share any research that may have come out of the program. The use of social media by scientists is becoming more popular, especially on commonly used platforms such as Facebook and Twitter (Collins, Shiffman, & Rock, 2016). Social media is utilized by many vessel programs, including the Nautilus. Additionally, providing opportunities for teachers and students to experience a vessel up close allow for a deeper understanding and engagement. For example, the JOIDES Resolution promote Teacher at Sea programs, which allow educators to join a research cruise, where they play an integral role in science communication, while also gaining valuable experience in oceanographic research. Outreach efforts may include video editing, blog writing, or social media managing.

2.4.5 Website Design

Web-based access to data via data portals has increased in recent years, with the implementation of programs such as Data.gov, the federal government's open data site. Launched in 2009 by the U.S. General Services Administration (GSA), Data.gov has grown from 47 to over 200,000 publicly available datasets from hundreds of data sources including federal agencies, states, counties, and cities (Kim, 2019).The use of web-based technologies to improve scientific relevance, awareness of oceanographic and stewardship issues, and knowledge of the current state of the oceans appears to be a valuable and feasible option for both researchers and educators (Reed, Payne, & Babb, 2005). Effectively designed sites can allow us to bring real world research experience to teachers and their students (McLaughlin, 2010). Additionally, utilizing websites showcasing authentic data can promote deeper learning of science and math concepts, as well as foster engagement using real-world investigations (McKay, S., Lowes B., McGrath P., Lin E., Leach, M., 2007).

When it comes to successful website design, developers have approximately 50 milliseconds to make a good first impression on those visiting (Lindgaard, Fernandes, Dudek & Brown, 2006). What constitutes a good first impression? According to the 2014 study *Evaluating the Usability of Educational Websites Based on Students' Preferences of Design Characteristics* (2014), usability is key. Researchers identified five areas that are critical to designing a website for the best usability. These areas include navigation, organization, ease of use/communication, design, and content (Hasan, 2014). The Data Science for the Public Good Program (DSPG) at the Social and Decision Analytics Laboratory (SDAL), a part of the Biocomplexity Institute of Virginia Tech additionally stressed the importance of having a well-designed homepage that displays data categories and a search function (*Criteria for Open Data Portals Offer Best Practices for Websites*, 2016).

Overall, the literature review pointed to a general disconnect between researchers and teachers, and a concern for the data DL and STEM literacy in the United States. However, this research also identified multiple areas that would require additional information, on topics such as the best practices for conducting data outreach and challenges faced by researchers, teachers, and their students when using data. Little research was found on marine science data-focused learning in American high schools, or data literacy levels of high school students in general

2.4.6 Objectives

The objectives of this research are:

1) Identify the barriers commonly faced by researchers using data in outreach efforts, and teachers implementing data in their classroom.
2) Identify potential solutions for overcoming those barriers.
3) Make informed recommendations on how programs can provide researchers, teachers, and their students with the resources they need for effective data use.

2.5 Methods: Identifying Needs and Best Practices

To collect information about the state of data literacy in teachers and their students, this study reviewed 8 years of survey data from data-focused educator workshops, and conducted interviews with high school educators and educator focused professional development providers. Additionally, this research evaluated data portal websites and gathered feedback on usability from high school teachers, as data portals are a common tool for delivering data and educational materials. Finally, interviews were conducted with marine science researchers, to gain their perspective on working with data in outreach, working with teachers, and the challenges faced when conducting education and outreach efforts.

2.5.1 Stakeholder Interviews

Semi-structured interviews were conducted with high school science and math teachers, marine science researchers from a variety of specialties, and professional development providers. Approximately 100 inquiry emails in total were sent, with a response rate of 32 completed interviews. Of those, 60 emails were sent to high school science and math teachers, with 15 teachers electing to participate in an interview. The majority of these were located in public schools in the Willamette Valley and along the Oregon Coast. Approximately 30 emails were sent to researchers with 11 researchers choosing to participate. All researchers were based in the United States, and the majority were located on the West coast. Approximately 20 emails were sent to professional development providers, with six electing to participate in interviews. These participants were affiliated with universities, federal programs, and other organizations.

The design and analysis of the interviewss operated under Grounded Theory. Grounded theory enables the researcher to identify key patterns or areas of interest through a process of constant comparison of data. Rather than beginning the research process with a specific hypothesis, it begins with a general understanding of a phenomenon. Initially, inductive reasoning generates codes from the data, which assists in the development of theory, identification of future data collection, and specifies important questions to ask (Walker & Myrick, 2006)

The sampling method was a modified snowball sample, as each interviewee would provide additional contacts they felt would be interested in and useful to the project. Because of this, teachers in the sample were at a variety of experience levels regarding the use of real data and RTD, ranging from little or no experience to regular (weekly) use. Due to the sampling method and participants, the results obtained may not be representative of teachers and researchers throughout the U.S. Interviews were conducted via telephone or in person, lasted an average of 30 minutes, and were transcribed and open- coded using the qualitative analysis software MAXQDA. Open-coding refers to a reiterative review process which involves rereading transcripts and highlighting key trends, words, or phrases associated with the research objective (Khandkar, 2009).

2.5.2 Review of Professional Development Surveys

The Monterey Bay Aquarium Research Institute (MBARI) Education and Research: Testing Hypotheses (EARTH) workshop is a 5-day professional development opportunity for formal educators from across the United States, emphasizing the use of real data in the classroom. This project utilized 8 years of MBARI EARTH pre-surveys administered to attendees at prior workshops, in addition to a sample of 17 completed pre and post surveys given to participants of the 2018 MBARI EARTH Workshop which was held in Newport, Oregon in June of 2018. Pre-survey (completed 1-2 months before the workshop) reviews were intended to help gain baseline data and inform development of the workshops, and included questions aimed at identifying prior knowledge and experience of data-use as well as establishing comfort levels for participating educators. Post-surveys (completed the final day of the workshop) included feedback about the data-focused workshop, including components that were most impactful and what materials and resources they found most engaging and effective.

Many of the key questions in the survey were open-ended, and were coded using an open-coding technique to identify any key themes in participant feedback. All surveys were collected online, and sample size, location of workshop, and workshop dates varied by year (Table 2.1).

Year	Number of Teacher Surveys (Pre)	Number of Teacher Surveys (Post)	Location	Time Frame
2018	29	20	Newport, OR	June 24th – June 29th
2017	21	N/A	Monterey, CA	July 16th – July 21st
2016	21	N/A	New Brunswick, NJ	June 24th– June 29th
2015	31	N/A	Newport, OR	July 19th – July 24th
2014	20	N/A	Monterey, CA	July 27th – Aug 11nd
2013	19	N/A	Honolulu, HI	July 14th – July 19th
2012	21	N/A	Wilmington, NC	July 8th – July 13th
2011	N/A	N/A	Kasitsna, AK	July 29th– Aug 2nd
2010	20	N/A	Hillsboro, OR	July 11th – July 16th

Table 2.1: Year, number of surveys, location, and time frame of MBARI EARTH workshops from 2010 to 2018.

2.5.3 Website Review & Website Survey

An initial collection of 15 websites designed to provide data (data portals) were located on the internet via a Google web search, and were reviewed for a number of factors including (a) the presence of an "education" or "teacher" tab; (b) how many clicks it took to find relevant content; (c) if tutorials on how to use the portal/resources were available; (d) the availability of lesson plans or activities; (e) the opportunity to provide “feedback;” (f) if the portal offered canned data, real-time data, or both.

Once stakeholder interviews were completed, a secondary list of five additional data-focused web resources was collected stemming from suggestions by interviewees. These additional resources were reviewed using the same format as the original 15 websites. The full list of 20 portals were then provided to high school teachers attending a data-focused workshop in January of 2019, which was hosted by the Science and Math Investigative Learning Experiences (SMILE) program at OSU. Teachers were asked to explore the web portals for approximately 20 minutes, then reflect on the portal’s accessibility, usability, challenges encountered, resources needed to fully use the portal, and recommendations for improvement. The sample size in this group was small (12 individuals) with limited access to the portals due to a lack of computers and a federal government shutdown that further prevented access to some of the intended websites. Thus, not all portals in the original review were included in the teacher review.

2.6 Findings

2.6.1. Teachers

The aim of the educator interviews was to identify a broad reaching definition of what “good data” or usable data are, identify any existing challenges facing teachers when attempting to implement data use in their classrooms, identify resources that are useful to teachers, as well as get a better picture of what future resources are needed to fill existing gaps. The sample of teachers interviewed varied in their data-use experience, with some using data consistently in their classes each week to others who rarely or never used real data in lessons. The combination of experience provided a wealth of information, and teachers who regularly use data often elaborated on why and how they reached their current level of comfort and confidence. In addition to the interviews, a teacher survey of existing data-focused websites was conducted.

2.6.1.1 Defining Good Data

Teachers were first asked to define what they consider to be “good data” to utilize in their classroom. All responses generally fell under three themes; relatability, formatting, and consistency. The idea of data having to be relatable for students was identified as very important by the majority of teachers. *Relatability* of the data means that data needs to hold some sort of meaning for students working with it. Whether that means data was collected locally or the data has a clear connection to students or issues they care about; data needs to tell a story. Without that story, teachers agreed that students would not be interested, and it would not be a “good data” set for them to use.

Of equal importance as relatability is *formatting*, specifically how a data set itself or a data-focused website is formatted. The teachers interviewed preferred clean, simple data available on an easy to use platform. Data needs to be presented in a way that is somewhat familiar or easy to navigate for teachers (Excel). If data cannot be presented in a simplified manner, and there is no guidance for how to navigate the data, teachers are likely to label it is as “bad data” or data that are not worth the effort to utilize in a classroom.

Fifty-three percent of teachers mentioned *consistency* as a parameter of importance. Consistency, according to interviewees, refers to a data set not having significant variation, allowing repeat analysis to be done by students that will reliably produce the expected results time and time again. Data that are not consistent could result from things such as malfunctioning machinery, biological activity interfering with equipment (such as algae growing on a sensor) and the little time available for data to be analyzed and/or corrected before it is reported. Data-sets with anomalies (for example, a downed buoy) can potentially be used as a learning opportunity, but for many teachers means more things for their students to struggle with.

2.6.1.2 Defining Good Real-Time Data

Once teachers established what they considered to be "good data," they were asked about their RTD use. Did they utilize RTD in the classroom? If they did, how would they define "good RTD" to utilize? Only 4 teachers (27%) used RTD regularly in their classroom, and felt confident in their abilities to locate and utilize them. Seven teachers had attempted to use data in the past, but gave up after struggling with them, and the remaining 4 teachers had never tried to use RTD at all (Figure 3).

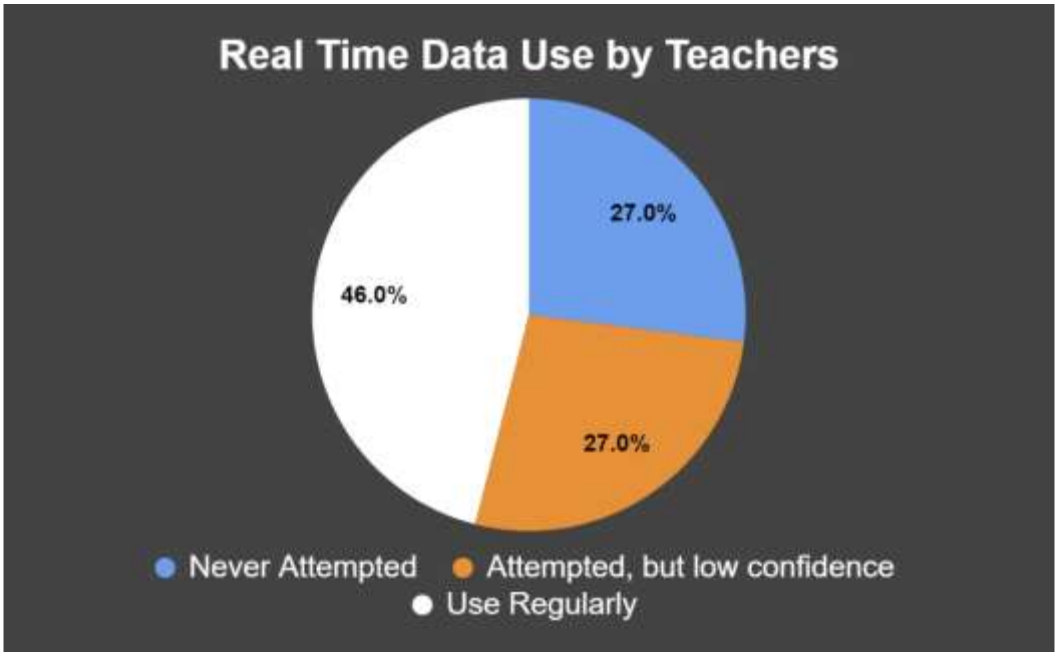

Figure 2.1 Teachers and their real-time data use

Generally, the 27% of teachers who felt confident defined good "RTD" with a similar definition to good data. Although, a heavier focus was placed on consistency, as there can be a higher chance of getting measurements that look "wonky" in RTD that make implementing an activity more complicated. The 73% of teachers that did not feel confident using RTD or had never used RTD at all either declined to give feedback, or referred back to their definition on good data in general.

2.6.1.3 Identifying Barriers

There seemed to be consensus among teachers on challenges that prevented them from effective data use in the classroom, no matter the level of experience held by the interviewee. Of the numerous suggestions, all interestingly coordinated with the same barrier themes from the researcher interviews - lack of time, lack of knowledge and lack of support (Figure 4).

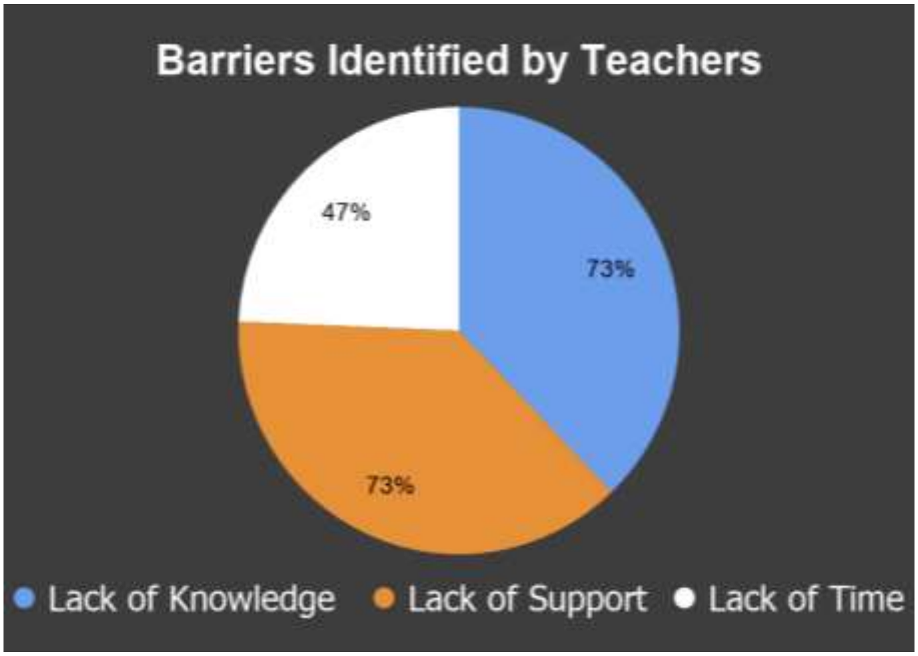

Figure 2. 2: Percentage of common barrier themes identified by teachers.

For teachers, lack of time is something they experience with or without RTD use. Often, they work overtime to stay on top of things and are expected to balance everything from lesson plans and grading, to large class sizes and meeting state standards. Teachers felt strongly about the time commitment involved with attempting to use RTD, and identified difficulty locating a reliable source of RTD and using web portals, confusion in downloading and reformatting data-sets, and matching real-time data to NGSS requirements as major barriers.

A lack of knowledge is another key theme for teachers. For many of the teachers, they listed not knowing where to find local RTD in the first place as a main challenge. Additionally, they mentioned a lack of experience in matching real-time data to science education standards requirements. Lack of knowledge also applies to the students in these teachers' classrooms. Per NGSS, students are expected to have a certain level of data literacy when they enter high school and increase it as they progress through. However, teachers voiced that many of their classes do not come in appropriately prepared to work with data. A lack of knowledge on the student's part means teachers have to devote additional time to improving their foundation in data literacy, before being able to implement RTD focused learning.

Finally, a lack of support was felt by some teachers. For the four teachers who felt confident in their data use, they also expressed feelings of having adequate support. Support can materialize as resources given from the administration, such as paid time for professional development in addition to providing technology for the classroom. Some teachers had access to "Chromebook carts," a newer resource for classrooms which provide individual Chromebooks for each student to use. For other teachers, not having access to technology in the classroom or having technology that isn’t always reliable is a key barrier. In addition to lack of support from the administration, teachers can also feel a lack of support from data-providers themselves.

2.6.1.4 Identifying Solutions

While teachers had a significant number of barriers they faced, they were quite explicit in their ideas for how to overcome them. Most solutions were directed towards remedying a lack of knowledge and saving teachers time. Solutions for a lack of support from the administration were more difficult for teachers to identify, so most recommendations revolved around how data providers could better provide support. Identified solutions included data-focused lesson plans with RTD extensions, as well as lesson plans or ideas that could be used by both science and math teachers working cooperatively, and professional development focused on providing teachers with their own foundation in data-use. Additionally, teachers recommended an increased public presence of data providers at educator events, to raise awareness of available resources. Teachers seemed to have a preference for a website-focused approach for accessing and using information on resources mentioned above as well as accessing the data itself. Teachers want step-by-step information on how to access, format and use data so having an additional help section on the website is key.

2.6.1.5 Website Review & Teacher Website Survey

Since it is clearly important for teachers to have an accessible web-portal and online resources, a review of existing data-portals was conducted (Table 2.2) in addition to teacher interviews. Portals were then provided to a group of teachers attending an educational workshop at OSU, and asked to review them on a series of questions regarding their comfort levels with the usability of the portal.

Review Criteria	Ratings or Feedback Available	Education Tab	Tutorials or Supplemental Information Available	Curriculum and/or Lesson Plans Offered	More Than 2 Clicks to Content	Real Data Offered	Real-time Data Offered
Number of Websites (20 total)	2	14	8	18	9	20	19

Table 2.2: Summary of data portal review

The number of teachers participating were too few to review all data portals, and some federally funded sites were inaccessible or provided limited access due to the January 2019 government shutdown. Because of this, the website survey findings were not as extensive as intended, but did provide general feedback that was consistent with interview findings. The majority of teachers (9 of 12) disliked their websites which were constructed more as a direct data-portal, with little to no guidance on how to use the website and little to no resources for teachers. Common complaints focused on time to find content, lack of organization, lack of information, and lack of help (Table 2.3). Teachers that felt satisfied with their website exploration identified the benefits of being able to find content quickly, and having a wide variety of content to select from.

Time	Organization	Information
"Hard to find data – too many clicks!"	"Very difficult to find and understand data applicable to student level activities."	"Needs more direct information for teachers to use with lesson plans or printable handouts."
"I don't know where to start looking, I don't have enough time."	"Too much lumped together -hard to navigate and find data."	"Needs tutorials!"

Table 2.3: Common feedback for selected data-focused resource websites

The combination of teacher interviews and website surveys provided an in depth look at the challenges facing high school teachers today, as well as the opportunities for providing them with the resources they need to succeed. The sample of teachers was mixed in their experience, with four that felt confident in the use of RTD, seven having attempted to use it but did not feel confident to continue, and four who had never tried to use it. Despite a difference in experience levels, teachers generally identified relatability, formatting and consistency as the key parameters affecting what they consider to be "good data." Data needs to mean something to their students, be in a form that is easy to work with and be consistent enough that it doesn't impede the success of an activity's ability to meet educational goals. When it came to identifying barriers, teachers struggled with the same key themes as the researchers; lack of time, lack of knowledge and lack of support. With teachers already having to balance a variety of things to keep their classroom running smoothly, there is little time left over to devote to locating, downloading and using RTD. Since many teachers did not feel comfortable in their own foundation in data literacy, as well as not feeling supported by their peers, administration or data-providers, there is a need for professional development opportunities, easy to use websites and pre-made lesson plans that already incorporate RTD in them.

Because websites and professional development were advocated for by teachers, the website survey, interviews with educational professionals who specialize in professional development and the review of the MBARI EARTH Workshop surveys were conducted to provided additional insight to what data providers should consider when designing and implementing future projects.

2.6.2 Professional Development

A major theme occurring in these surveys was the importance of building relationships and collaboration. A major attraction to this workshop in particular was the opportunity to foster relationships not only between teachers, but between teachers and researchers as well. When asked about what aspect of the workshop was most attractive or useful, one teacher shared, “absolutely hands down the presentations by researchers. Wow. Especially because I have such local application. Great sources from amazing people!” Learning about research and data directly from the source, while allowing teachers to ask questions and investigate was a valuable opportunity for teachers, who felt comfortable learning the content “from the source,” through researchers. Toward the end of the workshop, teachers were allowed to collaborate together to build curriculum, utilizing what they learned and potentially using researchers as a resource. Overall, this collaborative environment was very attractive to teachers.

Demographics in each survey were mixed in terms of years of teaching experience, comfort with data use, and education background. Generally, teachers with more teaching experience and repeat MBARI EARTH attendees ranked their data-use in the classroom as more consistent than teachers with less teaching experience and/or first-time attendees. Overall attendance across the surveys indicated that an average of 40% of participating teachers had attended a previous MBARI EARTH workshop. This indicates the potential lasting value that data intensive workshops such as MBARI truly have, if teachers continuously feel there is more to be learned each year.

In the comparison of pre to post surveys from the 2018 workshop, teachers provided ample feedback about their experience. Perceptions of knowledge regarding oceanographic topics such as research vessels, shipboard research, microbes, climate change, etc., moderately increased for the majority of teachers. Additionally, attendees were asked to rank their confidence in teaching data topics such as, using real data to develop testable questions, creating data visualizations, and accessing real data for science investigations on a scale of 1 (very poor), to 5 (very good). In the post survey, all participants ranked their confidence from “fair” to “very good”, with zero considering themselves to have “very poor” confidence.

Significant challenges highlighted include some teachers feeling overwhelmed with the amount of information covered in general, and not as much time with researchers as they would have preferred. However, teachers appreciated breaks in the content for experiences out of the classroom, such as tours of facilities, vessels, or the surrounding area. Additional benefits highlighted by teachers include the timing of the workshop (late June) and the suite of incentives offered (hotel, food, compensation for constructing curriculum, etc.) Attendees generally supported continuing relationships with researchers utilizing communication in the classroom (via Skype), and many suggested improving circulation of MBARI EARTH materials by attending educator conferences, such as the national science teacher association (NSTA) conference.

2.6.2.1 Interviews with PD Providers

The aim of the professional development interviews was to provide additional insight into the successful design and implementation of PD opportunities, as well as provide further commentary on the barriers facing researchers and educators. In general, information gathered from PD providers supported the results from the teacher and researcher findings. These PD providers commonly identified time, support, and knowledge as barriers they have seen these stakeholders attempt to navigate. Overall, the suggestions for designing PD focused on raising the comfort and confidence levels of stakeholders, and assisting them in navigating these barriers through effective timing, incentives, and organization.

These PD providers also recommended a multi-day schedule for workshops for groups of no more than 20 teachers, ranging from two days to four and a half days, depending on the amount of information to be covered. Because teachers have a larger time commitment with the workshop format, incentives should be offered to increase the value and attraction to potential attendees. Incentives can represent actual material items, such as stipends, lesson plans, food, and hotel stay, but also can reflect unique opportunities. For example, working with researchers in a small group setting (such as the MBARI EARTH workshop), or the opportunity for science and math teachers to work cooperatively. One PD provider spoke on the potential for math and science teachers' "pairs" to work collaboratively throughout a workshop, ultimately building both a relationship with each other and potentially producing an activity incorporating data by the end. Timing of the workshop itself was recommended to be in late June, as teachers finish up their school year, or late August, as they prepare for a new school year.

Suggestions for the organization of a workshop from PD providers were similar to those requested by teachers. Having a small selection of activities available, and walking teachers through them step-by-step, allowing them to ask questions and work through problems themselves. This way, teachers will be confident in sharing these activities with students, and helping them overcome any potential challenges with the data. Activities shared at these opportunities would ideally be aligned with any relevant state standards, such as Common Core and Next Generation Science Standards (NGSS). Allowing teachers time to communicate and collaborate with each other throughout the workshop was also identified as important, with recommendations that participants form a “learning cohort.” This learning cohort could potentially participate in the workshop process further, by taking evaluation surveys, having a collaborative space such as a social media page or email blast to share thoughts and ideas, and even participating in a follow-up webinar.

2.6.3 Researchers

Overall, researcher interviews gave important insight into the root of the data facilitation problem. Researchers generally agreed on the definition of “effective outreach” as involving successful communication of information from a presenter to a specific audience, and that the effectiveness could be measured through engagement and behavior change. Researchers found it more challenging to categorize the effectiveness of marine science outreach as a whole, and the most common answers commended current outreach efforts while simultaneously stressing the need for improvement. Researchers also differed in their reported levels of confidence and the amount of outreach effort they were currently conducting. The sample group was a mixture of confident, outreach pursuing researchers and less confident individuals who didn’t feel they had enough understanding to actively pursue outreach. Despite this range in confidence and outreach efforts, barrier responses generally fell within three key themes: lack of time, lack of knowledge, and lack of support. Although lack of time was generally consistent across all responses, lack of knowledge pertained to a variety of topics such as NGSS, communicating science to different age/education groups, and not knowing how to utilize social media. A lack of support stemming from researchers’ affiliated institutions, in addition to a lack of support through other programs, is a clear culprit in researchers feeling overwhelmed and unable to seek the assistance they need to address education related questions.

Marine science researchers are critical in the transfer of data from research vessel to classroom. Identifying common themes, barriers and opportunities is necessary to better help facilitate the flow of data. Interviews conducted with researchers sought to identify a general definition of what “effective outreach” means to researchers, identify their current effort and comfort level in their education and outreach activities, what barriers they faced, and what potential solutions there are for overcoming those barriers.

2.6.3.1 Defining “Effective Outreach”

Researchers were asked, “How would you define effective outreach?” and “Overall, do you think the scientific community is doing a good enough job at translating science to broader communities?” There was a consensus that effective outreach involves a successful communication of information from one person to a specific audience. There were two ideas that appeared in terms of “measuring” that success; engagement and behavior change. Evaluating researchers' translation of science overall was difficult for most researchers to answer. The majority of responses were some form of "yes and no." Some respondents leaned towards the side of "inadequate but with room for improvement," and "adequate but it could always better."

2.6.3.2 Evaluating Current Efforts

Researchers were then asked "do you use your own data in outreach efforts?" and "what audience do you feel the most comfortable working with?" to see if there was a common effort being put forth by marine researchers using their own data, as well as to identify any commonalities in comfort levels or audiences being targeted.

All researchers had some sort of education and outreach experience using their own data (ranging from marginal to extensive), with some stating the majority of that came from their time in graduate school or as Graduate STEM Fellows in K-12 Education (GK-12). The GK-12 Program supports graduate students in STEM, through interactions with teachers and students in K-12 schools. Graduate fellows can improve their communication and teaching skills while enriching STEM content and instruction for their K-12 partners (National Science Foundation, n.d.). Researchers levels of comfort varied with experience. For example, the researchers who had been a part of GK12 fellowships or done classroom work as part of their graduate studies perceived themselves as being most confident with a K-12 audience, with one researcher particularly enjoying working at the high school level. Researchers who had not had K-12 experience, reported their comfort level was greater sharing at the undergraduate and graduate levels, in addition to working with informal audiences.

2.6.3.3 Identifying Road Blocks

Researchers were asked to "identify any challenges you see associated with doing outreach for a K-12 audience. Generally, responses fell under the key themes of "lack of time," "lack of knowledge" and "lack of support" (Figure 2.3). Uncoincidentally, the three themes are interlinked, as a lack of resources can lead to a lack of knowledge and a lack of time.

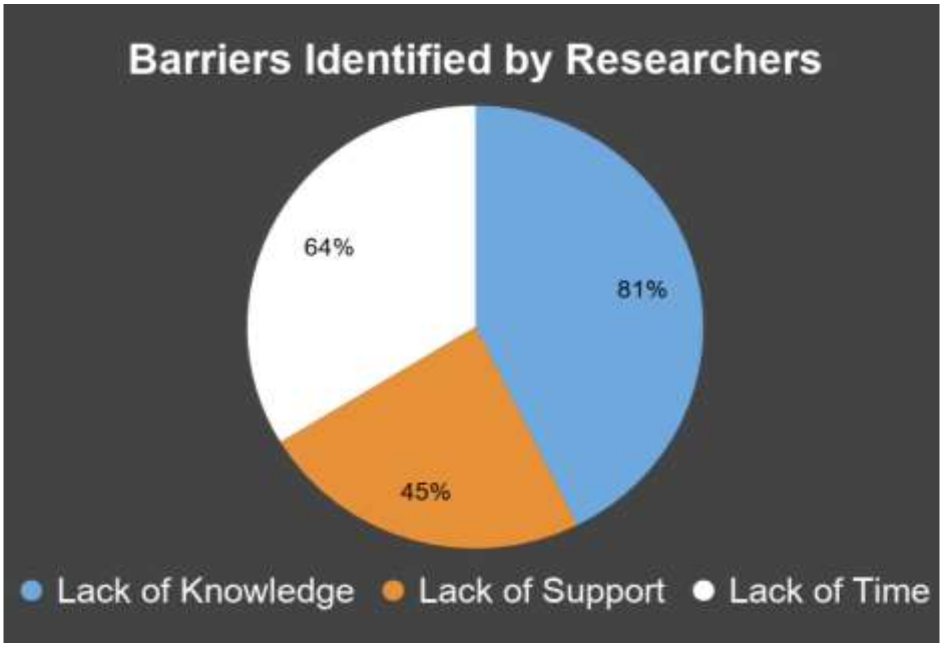

Figure 2.3 Percentage of common barrier themes identified by researchers.

A "lack of time" presents the question "lack of time to do what?" When considering these researcher responses, it means everything from not having enough time to design activities, learn state science standards, better themselves at "newer" concepts of outreach like social media, not having an audience for a long enough time or not being able to fit outreach into their schedules due to other responsibilities. Fitting efforts into their schedules is a problem on both land and sea. In the office, researchers are expected to write grants, conduct research and publish in academic journals. At sea, they are often subjected to specific schedules packed with setup, research activity and data analysis, with little time to squeeze in writing a blog post or skyping with a classroom.

The “lack of knowledge” theme involves a group of barriers researchers referred to in terms of not knowing how to do something related to outreach. For example, a common item is not knowing how to “scale down the science,” that is, removing scientific jargon and simplifying data so the average student can comprehend it. Additionally, it was mentioned that they often struggle with the design and implementation of activities with little to no knowledge of Oregon’s NGSS standards, what data is appropriate for what age group, and not knowing how to utilize alternative sources of education and outreach like social media.

Finally, the “lack of support” refers to researchers’ perception of excessive pressure from academic institutions to perform or the lack of resources available to them to help overcome barriers. The idea that researchers are not “rewarded” by their respective institutions for doing education and outreach was a theme present in both researcher interviews as well as interviews with the professionals who work closely with them. When given the opportunity to talk about any existing resources that have assisted researchers, only one was able to give a definitive source, and one shifted the discussion to how teachers are the stakeholders that really need the professional development.

2.6.3.4 Communicating Science

After being asked to think about and share challenges they faced when doing outreach, researchers were asked to identify any potential resources that could be useful to them. Most suggestions were centered around resources that would increase personal knowledge through professional development and educational products, thus saving time. Professional development that would allow practice with simplifying science and speaking with different age groups and audiences was a recurring theme. One interesting topic that came up as an opportunity for researchers to better facilitate the transfer of data was social media. In 2015, 50% of researchers surveyed used Facebook or Twitter in their professional lives, while 21% used Instagram (Collins, Shiffman and Rock, 2016). With billions of people using social media, this could be a promising avenue for science communication. This is an area where additional research could result in recommendations on how to use these tools more effectively

Overall, the researcher interviews gave important insight into the root of the data facilitation problem. While researchers generally agreed on definitions of effectiveness in outreach, as well as the state of translating science to broader communities, they varied widely in levels of confidence and how much outreach they were pursuing. The sample group was a mixed bag of confident, outreach pursuing researchers ranging to less confident researchers who didn’t feel they knew enough to actively pursue it. Despite the range in confidence and outreach efforts, barrier responses generally fell within three categories; lack of time, lack of knowledge, and lack of support. While lack of time was generally consistent across all responses, lack of knowledge pertained to a variety of topics such as NGSS, communicating science to different age/education groups, and not knowing how to utilize social media. A lack of support stemming from researchers affiliated institutions, in addition to a lack of support from local resources is a clear culprit in researchers feeling overwhelmed and unable to seek the assistance they need to answer education related questions.

2.7 Conclusions

In the end, streamlining the transfer of data from researcher to teacher to student depends on providing stakeholders with the resources that they need to successfully participate in this effort. Time-saving resources will be key, and should assist stakeholders in building confidence levels with using data in education and outreach.

2.7.1 Teacher Resources

Data-focused professional development opportunities for educators are crucial to the success of the data-focused education and outreach efforts. There are few existing data-focused PD opportunities for Oregon teachers, with the most recent being the 2018 MBARI EARTH Workshop, which rotates its location each year. Interviews with professional development providers identified topics that would make a successful PD experience including duration, incentives and content. The review of eight years of MBARI EARTH pre surveys, as well as the 2018 post surveys provided additional insight on what was attractive about the workshop, how their comfort levels using data changed over the course of the workshop, and how their perceived knowledge about oceanographic topics changed over the course of the workshop. Ideally, a future workshop would take place in late June and have a duration of three to five days. Additionally, attendance should be kept low (around 20 individuals) to maximize support for each teacher, and teachers should be provided with incentives (stipends, take-home materials, meals, field trips, and opportunities to collaborate with each other and researchers). Finally, one to three data-focused activities should be taught to teachers step by step, and they should be provided with follow up communication after the event to provide additional support.

Additionally, effective lesson plans are a valuable resource for Oregon teachers, and should be designed to accommodate a variety of subjects, knowledge levels and state standards. To fully support data literacy of Oregon students, lesson plans should be implemented using both relevant canned data and real-time data. Activities should be first run using the canned data to allow teachers to assess existing levels of data literacy, and then through a second activity or through an extension, incorporate real-time data. This way, students get used to working with data that are consistent and predictable, and are better prepared to work with real-time data.

The best way to provide teachers with lesson plans and information about PD opportunities is through a web portal. Ideally, this portal would be linked off of the main RCRV website, to reduce clicks to content (1-2 clicks) and time spent locating lesson plans or data. If and when the educator portal is completed, a focus group or survey should be conducted on its effectiveness with local teachers. Overall, effective educator portals would have a link for teachers when they require additional help, such as “need help?” or “more help here” link. Additionally, step by step instructions on how to navigate the website, as well as how to locate and download data (if possible, this would be especially helpful in video format). Lesson plans should be available and organized or searchable by topic, subject or state standard. Contact information should be available both for someone to answer teacher questions (“connect with us”) and information for researchers interested in classroom participation (“connect with a researcher”). Any available information on upcoming professional development opportunities should also be made available in a clear and concise way. Video resources should also be made available, including vessel building efforts, research efforts, or videos of researchers talking about their work. Finally, there should be links to any social media pages or blogs as well as an email list, where teachers receive information on upcoming events, lesson plans, etc.

2.7.2 Researcher Resources

Future professional development opportunities are a valuable resource for researchers. Professional development should focus on introducing researchers to what level of language and attention is appropriate for a variety of audiences. For example, introducing researchers to a variety of outreach techniques including utilizing social media, informal engagements like pub talks, as well as teaching in a formal learning environment. This could potentially lead into coverage of the Next Generation Science Standards, giving researchers a background on what students should theoretically already know by the time they have reached a certain grade, as well as education goals for various grade levels. It is also essential that researchers understand the three key themes for "good data" identified by teachers so they can design data-focused learning activities in a format that tells a story while being easy to utilize.

Once a foundation has been established, researchers could then work collaboratively with each other and potentially other education professionals to design activities based around their own work. In speaking with professional development providers, it was clear that these opportunities are most effective when spread out over a few days, providing a large amount of time for collaboration and reflection from participants. A 2004 study identifying best practices for communication workshops angled toward scientists utilized the following structure, which they call OPERA. Opening a question of interest, Prior knowledge discussion or assessment, Exploration through experiments/experiences, Reflection on results, and Application of learned concepts to new situations (Morrow & Dusenberry, 2004).

2.7.3. Future Research

There are a variety of future research opportunities to supplement the findings of this research. These include (a) using real-time marine science data to support student learning in informal environments, such as museums or aquariums; (b) conducting additional research to see how data-driven learning can reach across different socio-economic and cultural levels, to better inform the design of future data-focused lesson plans and activities to be as inclusive as possible; (c) conducting research on the effectiveness of professional development opportunities through participant surveys and interviews; (d) conducting additional research on the usability and effectiveness of data-portals through surveys and focus groups, as findings were limited in this research; (e) conducting additional research to see how RTD can be applied across multiple disciplines, not just science, as some teachers expressed a desire for relationships between learning disciplines.

2.7.4 Informing Phase Two

Although this research helped to clarify the support needed for successful transfer of real marine science data between researchers and teachers, it also highlighted the fact that more research is needed on the effectiveness of utilizing data with the final stakeholders – students. Phase one of this thesis provided important background on teacher needs to inform the design and implementation of phase two. After finishing data analysis in phase one, it was determined that the curriculum design for phase two would require the use of relevant, consistent, clearly formatted canned data in addition to real-time data, for the best potential impacts on student data literacy.

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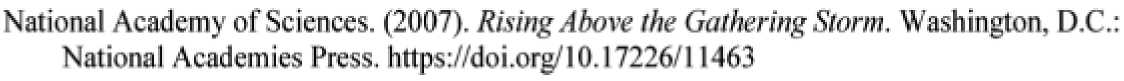

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Chapter 3

A Sea of Data: Connecting Oceanographic and Biological Data from the Oregon Coast

3.1 Introduction

High school students in the today's world have virtually unlimited access to enormous amounts of data at the touch of a button. Data inform and drive nearly every aspect of modern society, including retail, manufacturing and financial services, with scientific research (Jagadish et al., 2014). Often, students do not have the data literacy skills they need to properly understand data-focused activities in the classroom. In fact, only 21% of 16 to 24-year-olds consider themselves to be data literate (QLIK, 2018). No matter what career path they choose, understanding what data are, how to analyze data, and why data are important is crucial for students today (*Building Global Interest in Data Literacy: A Dialogue Workshop Report*, 2016). Targeting data literacy in high school is particularly critical, as leaving skill development to the post-secondary environment is unlikely to ensure that students are sufficiently prepared to participate fully in their workplace or society at large (Julien & Barker, 2009).

Using real data in the classroom, also known as "authentic" data, can improve data literacy in students (Kerlin et. al., 2010, Holmes et. al., 2015), as well as foster and improve skills such as interpreting data and engaging in arguments built from evidence (NRC, 2012). Authentic learning refers to activities and experiences that promote real world relevance and critical thinking, using complex problems that require significant time investment and intellectual resources (Lombardi, 2007). Utilizing authentic data can encourage students to identify connections between their lives and the data they are working with. This forms a sense of connection which can spark engagement in students (Doering & Veletsianos, 2007). When working without a sense of relevancy, the navigation of a data portal, analysis of a data set, or interpretation of output from an online visualization platform may appear more daunting (Kjelvik & Schultheis, 2019).

There are a variety of existing data-focused modules provided by programs such as the Monterey Bay Aquarium Research Institute Education and Research: Testing Hypothesis (MBARI EARTH), the Oceans of Data Institute (ODI), and the National Oceanic and Atmospheric Administration (NOAA) Data in the Classroom, covering topics from ocean acidification to the migration of marine mammals. Because the group of students this module was tested on were located on the Oregon coast, there was potential to provide them with a new, authentic learning activity utilizing local data that offered the all-important sense of relevancy to them.

Currently, a new source of real oceanographic data is preparing to provide teachers and students with authentic learning opportunities to be utilized in their classrooms. As Oregon State University (OSU) oversees the design and construction of three new regional class research vessels (RCRV), they are poised to become an important source of real-time marine science data. These new RCRVs will have “datapresence” capability, which is the ability to collect data and beam it back to shore with minimal turn-around time, allowing stakeholders to actively participate in and observe research in real time. This provides a unique opportunity for the RCRV team to foster communication and collaboration among researchers, teachers, and students, in an effort to stimulate both scientific and data literacy. Oceanographers are not the only users of data, and research vessels are not the only sources of data, but they provide an example and a contextualized learning opportunity for today’s students.

This four-lesson, RCRV-supported high school module seeks to develop data literacy through lectures, discussions, and hands-on activities. Using real, contextualized oceanographic data this research hopes to support students’ foundations in data literacy and foster additional growth by promoting the use of real-time data. Teachers often identify a need for data to be relevant to their students for them to be engaged (Kjelvik & Schultheis, 2019). Thus, the topics and data sources utilized in this module are from research conducted off the Oregon Coast, as these lessons were developed and implemented with high school students in an Oregon coastal school district. This curriculum also provides important and relevant information for teachers and students located elsewhere, and could be modified to include data from other regions.

3.2 Curriculum Overview

This curriculum module was designed according to the Kemp Instructional Design Model (Akbulut, 2007), which consists of 9 interdependent elements including identifying instructional design problems and specifying relevant goals, examining learner characteristics, identifying subject content and analyzing task components that are related to instructional goals, stating instructional objectives for the learners, sequencing content within each unit to sustain logical learning, designing instructional strategies for each learner to master the objectives, planning instructional delivery, developing evaluation instruments, and selecting resources to support learning activities (Akbulut, 2007). The model is circular rather than linear as opposed to the other curriculum design models. More specifically, the nine elements listed above are interdependent. Moreover, they are not required to be considered in an orderly way to realize the instructional learning systems design. What differentiates the Kemp model from most other models is that it considers instruction from the perspective of the learners, it provides a good application of the systems approach where the process is presented as a continuous cycle, and finally it puts a greater emphasis on how to manage an instructional design process (Akbulut, 2007).

Lessons Two and Three utilize the Jigsaw Cooperative Learning Technique (Tanner, Chatman, & Allen, 2003). The explicit goal of the jigsaw discussion is for students to share their expertise and to gather information from peers who have completed a different task. For example, in this module, students form various science parties and are assigned one of three sets of data. After completing their research task and communicating results to their fellow students, the groups must come together and identify how their sets of data work together to tell one, unified “story” about the ecosystem. This type of jigsaw approach has been successfully used to introduce students to the research literature of biology and provide peer support in understanding the complexities of language in written scientific communications (Fortner, 1999).

In the development of these lessons, a review of scientific literature was conducted, interviewed high school science teachers from a variety of subjects, and identified links to Next Generation Science Standards (NGSS). Through these methods, we recognized a need for a module that would provide detailed background and supporting resources for teachers, including activities that utilized “canned” data to solidify students’ data literacy foundations before engaging in extensions utilizing near real-time data. The module was implemented with biology classes from Taft High School, which is located in Lincoln County School District in Oregon.

The module was then revised following classroom experience in addition to teacher feedback, and is presented now in its revised form.

Throughout these lessons, students build their scientific and data literacy skills as they gain foundational knowledge of marine science concepts, investigate sets of real oceanographic data, practice their science communication skills, and explore a near real-time data portal. In Lesson One, students begin to build their understanding of oceanographic concepts by learning about the who, what, when, where, and why of marine science research. In Lesson Two, students are introduced to more practical applications of oceanographic research by working with three data sets collected off the Oregon Coast. Using the Jigsaw Cooperative Learning Technique, students break into groups and participate in a specific data-focused task where they read and analyze data, graph and map results, and then communicate their findings.

If classrooms have access to a computer lab or Google Chromebooks, there is an optional Lesson Three extension that utilizes near real-time data from the Northwest Association of Networked Ocean Observing Systems (NANOOS). This lesson allows students to not only explore a relevant data portal, but connect what they have learned about water quality, plankton, upwelling, and the Oregon coast while utilizing near real-time data. Finally, in Lesson Four, students discuss key concepts learned in small group settings and with the larger class.

3.3 Lesson Details

3.3.1 Lesson One: Introduction to Oceanography

Lesson One begins with a brainstorming and discussion session where students confer on what “big-data” are, how data impacts them directly, and why they think it is important to be able to understand and evaluate sets of data. This discussion will identify any existing understandings or misconceptions, offer an opportunity to clarify the relevance of this lesson, and set the stage for subsequent activities. After the discussion, students are introduced to the field of oceanography to lay the groundwork that will be built up on throughout the module.

Students are led through the “who, what, when, where, and why” of oceanography through a PowerPoint presentation and short videos highlighting relevant topics, and discussion questions focused on making connections between the importance of research, data literacy, and potential impacts of collected data. The lesson concludes with an optional video and an assessment through a One-minute Paper (Yamagishi, 2016). The One-minute Paper is designed to provide immediate feedback on student perceptions. Benefits of the One-minute Paper are that it provides feedback on how the main takeaways of the lesson were perceived, allows students to think critically and ask questions, and provides the teacher with feedback about misconceptions that should be addressed in subsequent classes.

3.3.2 Lesson Two: Practicing with Real Data

This lesson begins by setting the stage for students: they are oceanographic science parties who have just finished a research cruise and now they need to analyze their data. This scenario is modeled after an actual oceanographic cruise on the OSU Research Vessel, the *Oceanus,* which was conducted in the Fall of 2018. Students explore the type of data their science party “collected” on the mock cruise, then create visual representations for their data. Once finished with their individual activities, students practice communicating their work by designing and presenting scientific posters showing their results. Students will explain (a) their data collection method, (b) their data set, (c) their objective, (d) their results, (e) make an argument for why they think their data set is important. During the presentations other students take notes and ask questions of the presenters.

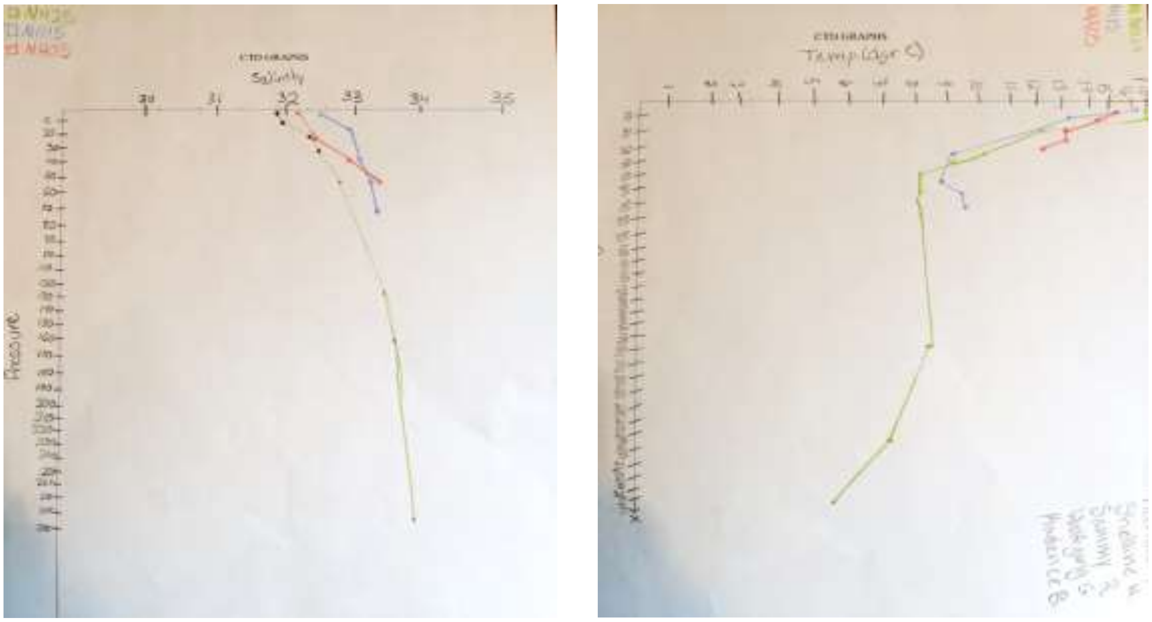

Figure 3.1: Examples of CTD graph results from a group participating in Lesson Two.

Once poster presentations are complete, students engage in an experience using the Jigsaw Learning Technique by discussing how their datasets are related and recognize that together their individual work tells one “data-story.” Students discuss how water quality is related to plankton, and how plankton is related to larger predators in an ecosystem. This discussion concludes with students reflecting on the nature of variability in ecosystems, and how one small change can have cascading effects on the entire ecosystem.

3.3.3 Lesson Three: Exploring Near Real-Time Data

Before beginning the near real-time data focused activity, students will brainstorm what “near real-time” data are and why they are important to a variety of stakeholders. Once finished, student will begin “Well, well, well,” a lesson offered by NANOOS, which allows students to make connections between the oceanographic concepts they have already investigated while exploring a near real-time data portal. This lesson requires access to an internet-enabled computer lab or Google Chromebooks, and includes a lab demonstration of upwelling. Utilizing this activity can potentially further support the data literacy skills of students, and help build confidence with visualizing and manipulating data (Kerlin, Mcdonald, & Kelly, 2010). Given that both educators and their students will have access to real time data once the RCRV datapresence system is live, it is important they are comfortable with similar data-portals and data visualization to effectively utilize this RCRV resource.

Figure 3.2: Screenshot of NANOOS NVS used in the “Well, well, well” activity.

3.3.4 Lesson Four: Wrap Up

In a final discussion, students will reflect on the topics covered by the module. Included in the discussion is information the students gathered about why oceanographic research and data collection are important, and how they are relevant to the lives of students. Students should end this module with a greater degree of comfort and confidence around working with data, and a new appreciation for how oceanography and marine science data impact their lives.

3.4 Challenges and Lessons Learned

Previous to classroom implementation, the participating teacher advised the module be extended in length from two to three days, which was accepted. Challenges with the implementation of the module in the classroom then arose when the existing data literacy skills of participating students was vastly underdeveloped. Rather than efficiently moving through each activity in the module, the majority of time was spent focused on lesson two, to focus on building foundational data literacy skills with students. This highlights a challenge that may arise when attempting any sort of data-focused activity. Although the data literacy of the participating teacher was high, their students were not equipped with the skills they should have gained from the previous year. This can put additional stress on an educator, who must try to balance both building the basic skills and introducing the standard-appropriate new skills.

The module has since been revised according to teacher feedback and classroom observations, and while incorporating a longer time frame, it is advised that educators wanting to implement this module in their classroom identify any existing data literacy needs of their students beforehand, to ensure they are prepared to fully participate in this module’s activities.

3.5 Conclusions

This oceanographic data-focused module seeks to provide educators with the background and resources they needed to build data literacy skills in students while using engaging and contextualized content. After completing this module, students will hopefully experience less intimidation when faced with scientific data and gain an appreciation for scientific research and related processes. At the conclusion of the module implementation, the participating teacher said, “the activity seemed to impact my students’ understandings of data and they don’t seem to be as intimidated by numbers and graphing now. I think initially some of their attitudes towards science may have shifted…. literacy is a process and I think the activities enhanced their understanding of how, why, and what scientists do.”

3.6 Acknowledgements

Many thanks to the teacher and students from Taft High School in Lincoln City, Oregon who participated in the development and testing of the original curriculum. Additional thanks to the educators and other professionals who provided insight on data literacy and data-focused learning, as well as the scientists who provided data to be used in the curriculum. This research and resulting project are funded by a grant from the National Science Foundation, which supports the Regional Class Research Vessel Project.

3.7 Standards

Standards **HS-LS2 Ecosystems: Interactions, Energy and Dynamics** **HS-LS4 Biological Evolution: Unity and Diversity**		
Performance Expectation(s) *The chart below makes one set of connections between the instruction outlined in this article and the NGSS. Other valid connections are likely; however, space restrictions prevent us from listing all possibilities. The activities outlined in this article are just one step toward reaching the performance expectations listed below.* **HS-LS2-1 Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.** **HS-LS2-2 Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.** **HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.** **HS-LS4-5. Evaluate the evidence supporting claims that changes in environmental conditions may result in (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.**		
Dimension	**Name and NGSS code/citation**	**Specific Connections to Classroom Activity**
Science and Engineering Practices	**Using Mathematics and Computational thinking** • Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. (HS-LS2-1, HS-LS2-2)	Students utilize data analysis and graphing skills to discover connections between water conditions, food sources, and presence of larger animals.
Disciplinary Core Ideas	**LS2.C. Ecosystem Dynamics, Functioning and Resilience** • A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant	Following the poster presentations, students will discuss the sensitivity of ecosystems, and how one

	over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. (HS-LS2-6, HS-LS2-2) **LS4.D. Biodiversity and Humans** • Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus, sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. (HS-LS4-6)	change can cause large effects throughout the system. Students discuss the relationships between humans and the natural world, identify ways humans are having a negative impact on it, and relate this to the importance of conducting oceanographic research.
Crosscutting Concept(s)	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS4-5)	Students discuss the relationship between phenomena, such as upwelling causing a higher source of nutrients in the surface water, leading to higher levels of productivity.

Table 3.1: Next Generation Science Standards (NGSS) for this module.

3.8 On the Web

The RCRV Project at Oregon State University is committed to assisting teachers in pursuing data-focused learning in their classrooms. Please visit our website for general information about the project, specifics about the ships, timelines and frequently asked questions. The RCRV outreach page is continually updated with new information about professional development opportunities, lesson plans, contacts and other helpful resources. As the project progresses and the *R/V Taani* goes live, lesson plans will integrate the real-time data collected from the vessel.

- A Sea of Data Module:
  https://ceoas.oregonstate.edu/ships/rcrv/outreach/
- “Well, well, well” Lesson Plan from NANOOS:
  http://www.nanoos.org/education/pdfs/well_well_well.pdf
- Regional Class Research Vessel (RCRV) Homepage:
  https://ceoas.oregonstate.edu/ships/rcrv/
- RCRV Education & Outreach Page:
  https://ceoas.oregonstate.edu/ships/rcrv/outreach/
- R/V Taani Construction Time-lapse Webcams:
  http://webcam.oregonstate.edu/rcrv1
  http://webcam.oregonstate.edu/cam/rcrv2/timelapse/2019-04-13.mp4
  http://webcam.oregonstate.edu/rcrv4

There are a variety of other programs that provide additional data-focused learning activities and resources for teachers, including;

- The Monterey Bay Aquarium Research Institute (MBARI) Education And Research: Testing Hypotheses (EARTH) Program: https://www.mbari.org/products/educational-resources/earth/
- The Consortium for Ocean Science Exploration and Engagement (COSEE):
  http://www.cosee.net/resources/educators/
- Oceans of Data Institute (ODI):
  http://oceansofdata.org/
- The National Oceanic and Atmospheric Administration (NOAA) Data in the Classroom:
  https://dataintheclassroom.noaa.gov/
- The National Estuarine Research Reserve System (NERRS):
  https://coast.noaa.gov/nerrs/education

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Chapter 4

Impacts of data-focused experiential learning on high school students' data literacy, attitudes, and beliefs about science.

4.1 Introduction

The amount and availability of data in the United States are rapidly increasing, and with this is a growing demand for a workforce that is both competent and confident working with large sets of data (NAS, 2018; Baker, 2017; Wolff et al., 2016; Caprile et al., 2015). The ability to make sense of data is considered to be a critical skill by many employers, and having such expertise can provide access to significant career opportunities given that jobs requiring data science skills are anticipated to grow 28% by the year 2020 (Markow, Braganza, Taska, Miller, & Hughes, 2017). Recent studies have shown the importance of having a data literate workforce to thrive in an ever-increasing technological society, maintain U.S. economic and scientific competitiveness, and enable people to tackle complex issues (National Research Council, 2011). These skills are particularly important for careers in science, technology, engineering, and math (STEM) (Gibson & Mourad, 2018). In the State of Oregon, where the research project highlighted in this article occurred, STEM job growth is prominent. In 2013, Oregon added more than 220,000 jobs, most of them being STEM related (Oregon Economic Review and Forecast, 2015). By 2020, it is projected that Oregon will have almost 40,000 new job openings per year in STEM fields, with nearly 94% requiring a postsecondary degree (Oregon STEM Employer Coalition, 2012).

The need for a data literate workforce is clear, yet there are growing concerns that K-12 students are not being prepared to fill that demand (Finzer, 2013; National Academy of Sciences, 2007). High school students are a particularly important age group, as they have extensive access to large amounts of data, yet struggle to critically evaluate and interpret data (Brem, Russell, & Weems, 2001; Schmar-Dobler, 2003). Additionally, as students advance from primary to secondary education, many lose interest in science and cease seeing it as a viable option for their future or associating it with their success (Chistidou, 2011). Research shows that a large portion of students who concentrate in STEM make that choice during their high school years (Maltese & Tai, 2011).

There is also evidence to support the notion that student relationships with science are influenced by their learning environments. Specific learning and teaching methods used by an educator have been shown to play a critical role in student success and pursuit of STEM (Barber & Mourshed, 2007). Generally, positively held attitudes (an evaluation, be it positive or negative, of an object, scenario, or situation) (Fishbein & Ajzen, 1975) toward science are related to teacher support, enthusiasm, teaching methods, and the opportunities available for student involvement (Hamre & Pianta, 2006). Thus, educators should be urged to foster greater engagement with students through innovative teaching practices or activities (Sheldrake et al., 2017). There is a substantial body of research that suggests tailoring teaching styles to suit student needs is an effective way for increasing engagement in the classroom topic (Bennett, Lubben, & Hogarth, 2007; Hennessy et al., 2007). Additionally, research points to the importance of students having positive attitudes and beliefs (linking objects and attributes together) (Koballa, 1989) toward science to be successful and engaged in their science classes

(Bowen & Bartley, 2014; Bybee, Mccrae, & Laurie, 2009; National Science Foundation, 2018; Osborne, 2003; Stephenson & Schifter Caravello, 2007).

It is clear that high school is a critical time for students to remain engaged in science so they may continue pursuing STEM in both their post-secondary education and careers (Beering et al., 2010; Holmegaard, Madsen, & Ulriksen, 2014). Given this, it is important to identify ways of invoking a paradigm shift in the student relationship with science in school. One potential way to create this shift is by engaging students in data-focused learning activities, as these activities can promote critical thinking skills and provide a sense of relevancy of science to the real world (Kerlin, McDonald, & Kelly, 2010; Gould, 2014). Data-driven learning can promote collaboration both in and out of the classroom, and aid in teaching self-reflection on a student's individual learning, as well as a student's collaborative learning (Lombardi, 2007). Other benefits from data-focused learning experiences include teaching students how to critically evaluate the integrity of data and discern fact from fiction, developing science communication skills, and allowing students to see the open-ended nature of the scientific process. This means that students also have the opportunity to discover discrepancies in a dataset or experimental design and to develop questions for further investigation (Culbertson, 2014; Manduca & Mogk, 2002).

Although there is research that focuses on solidifying data literacy (DL) skills within undergraduate and graduate students, due to the fact they arrive on campus with limited existing skills (Shorish, 2015; Carlson, Nelson, Johnston, & Koshoffer, 2015; Prado & Marzal, 2013; Stephenson & Schifter Caravello, 2007), research on data literacy instruction methods is lacking (Kjelvik &Schultheis, 2019). While the interest in utilizing data in the classroom and bolstering

DL skills is there, research is still needed to define desired learning outcomes and best practices for improving DL in students (Kjelvik & Schultheis, 2019). Additionally, there are few studies that have tested the efficacy of educational materials using authentic data in the classroom (Aikens and Dolan, 2014). As of 2019, there are also no studies evaluating the comparison of inauthentic data vs authentic data on student data literacy, interest and engagement, or studies evaluating data literacy using paper resources vs digital resources (Kjelvik & Schultheis, 2019).

One proposed research method put forth by Gibson & Mourad (2018) involves providing students with repeated practice using data, while prioritizing the discussion of the importance of data and how it can answer questions. This method is similar to that of the module discussed in this article, whose main objective is to assess the impacts of data-focused experiential learning on attitudes toward science, beliefs about science, and DL of high school students.

4.2 Background

4.2.1 Experiential Learning vs Passive Learning

For many students in the United States, educators are still utilizing passive lecture and note taking methodology (Cerbin, 2018). Students have shown distaste for this style, as well as other methods of passive teaching (Titsworth, 2001). Written exercises and copying notes from textbooks prove to be equally unengaging for students. It is these methods that perpetuate the idea that high school science is detached and too abstract from the lives of its students (Krapp & Prenzel, 2011). For students to be engaged in science and data literate, they should be participating in experiences and acquiring positive feelings throughout their science education

(Krapp & Prenzel, 2011). Positive experiences are related to the formation of positive attitudes toward and pique interest in science (Krapp & Prenzel, 2011). However, the opposite may also be true, as a negative experience in science can lead to an avoidance of the subject and the formation of negative attitudes toward science throughout their lives (Simpson & Steve Oliver, 1990). According to the Association for Experiential Education website, "experiential education is a philosophy that informs many methodologies in which educators purposefully engage with learners in direct, hands-on experience and focused reflection in order to increase knowledge, develop skills, clarify values, and develop people's capacity to contribute to their communities."

Educators who have incorporated experiential activities into their courses have reported multiple benefits including increased student enthusiasm, enjoyment of learning, perception of value, and improved performance on assignments (Hamer, 2000). Experiential learning also poses promise in the lasting impacts it has on students, as students who are physically connected with material and more physically active in the classroom generally retain more information (Burris, Garton, & Terry, 2005). When combining an authentic set of data with an experiential learning activity, there is the potential to foster growth in student DL, as well as increase their natural world comprehension (Schultheis & Kjelvik, 2015; Langen et al., 2014). Authentic learning refers to activities and experiences that promote real world relevance and critical thinking, using complex problems that require significant time investment and intellectual resources (Lombardi, 2007).

4.2.2 Beliefs About Science

Koballa (1989) stated that beliefs link objects and attributes together. In this research, students selected their level of disagreement or agreement on beliefs statements such as, “Science (object) is fun (attribute).” Having a positive set of beliefs about science means that students acknowledge and appreciate the role of science in understanding the world around them, and value the contributions of science to their own lives as well as society in general (Schiepe-Tiska, Roczen, Müller, Prenzel, & Osborne, 2016). Beliefs regarding how science is related to their personal life can inspire greater intention to engage in a science activity, which can motivate a better scientific performance (Pekrun, 2000; OECD, 2007). A student’s own beliefs in addition to those of his or her peers and parents can also influence their attitudes toward science (Schiepe-Tiska et al, 2016).

4.2.3 Attitudes Toward Science

Having a positive perception of environments such as their classroom are linked to both positive attitudes and positive learning outcomes of students (Nolen, 2003). Students who have positive attitudes about science show increased attention to classroom instruction and participate more fully in science activities (Osborne, 2003). Consequently, a negative attitude toward science can have an adverse effect on student engagement in science. Key themes such as difficulty or lack of interest correspond to behavior influenced by negative attitudes toward science, such as not asking questions, minimal participation in discussions, and a lack of effort on assignments (Gasiewski, Eagen, Garcia, Hurtado, & Chang, 2012). A negative attitude and/or negative perception have also been identified as important factors that restrict students from continuing career trajectories in science (Holmegaard, Madsen, & Ulriksen, 2014).

4.2.4 Data Literacy

Data literacy often refers to an understanding of what a set of data mean, and involves reading graphs and/or figures accurately, pulling supportable conclusions from data trends, and recognizing when data may be corrupt (Carlson, Fosmire, Miller, & Nelson, 2011). In a world that is heavily saturated with data, it is important to equip students with these skills as part of their overarching scientific literacy skill set (Donovan, 2008; Marx, 2013). With such an abundance of data available, it is of the utmost importance that DL be recognized as a necessary civic skill for the benefit of not only individual students, but also employers and society (Swan et al., 2009).

Data literacy is included in many educational standards, including the Next Generation Science Standards (NGSS) Analyzing and Interpreting Data practice, and many of the Common Core Math, English Language Arts (ELA), Social Studies, and Technical Subjects standards (“Read the Standards | Common Core State Standards Initiative,”“Read the Standards | Next Generation Science Standards”). No matter what career path students choose, having the confidence and ability to evaluate data will be integral to their success (*Building Global Interest in Data Literacy: A Dialogue Workshop Report*, 2016). Targeting DL in high school is particularly critical, as leaving skill development to the post-secondary environment is unlikely to ensure that students are sufficiently prepared (Julien & Barker, 2009). For this reason, focus should be directed to strengthening skill sets at an earlier age. Prado and Marzal (2013, p.124) noted that "...we feel that data literacy should be acquired gradually at all levels of schooling and even throughout individuals' lifetimes."

4.2.5 Research Questions

Despite the clear need for DL to be fostered in the classroom, and the potential that using authentic data in experiential learning activities may have, there is still a need for research to be conducted on practices for using data in the classroom to best positively impact students (Kjelvik & Schultheis, 2019). This study seeks to add to this area of research by investigating the three following questions:

1. To what extent does experiential learning incorporating authentic oceanographic data impact student levels of data literacy?
2. To what extent does experiential learning incorporating authentic oceanographic data impact attitudes toward science and beliefs about science?
3. How do data literacy, attitudes toward science, and beliefs about science change with instruction over time?

4.3 Methods

4.3.1 Experimental Design

This study involved a two-group panel design (Salkind, 2010), where two classrooms were designated as the experiential learning group (ELG), and two classrooms were designated as the passive learning group (PLG). All classrooms were taught by the same instructor, so there was no instructor effect. Given that both groups were exposed to new information, there is not a true "control" group in this study. Students completed pre-surveys one week in advance of instruction, post-surveys the final day of instruction, and post-post surveys approximately six weeks following instruction. Surveys were entered into Google Forms, which students accessed via Google Chromebooks in their science classroom. Each of the learning groups received the same first day of instruction, which included an introduction to the field of oceanography, as well as a general introduction to marine science data and how data relates to the lives of students (Figure 4.1). On the second day, the ELG participated in a hands-on activity acting as their own “science party” who needed to analyze, interpret, and communicate sets of real marine science data collected off the coast of Oregon. In comparison, on the second day, the PLG received a lecture on data-collection methods and their results, without participating in any hands-on activities. On the final day, both groups participated in a discussion reviewing the concepts they covered on oceanography, research, and the importance of data.

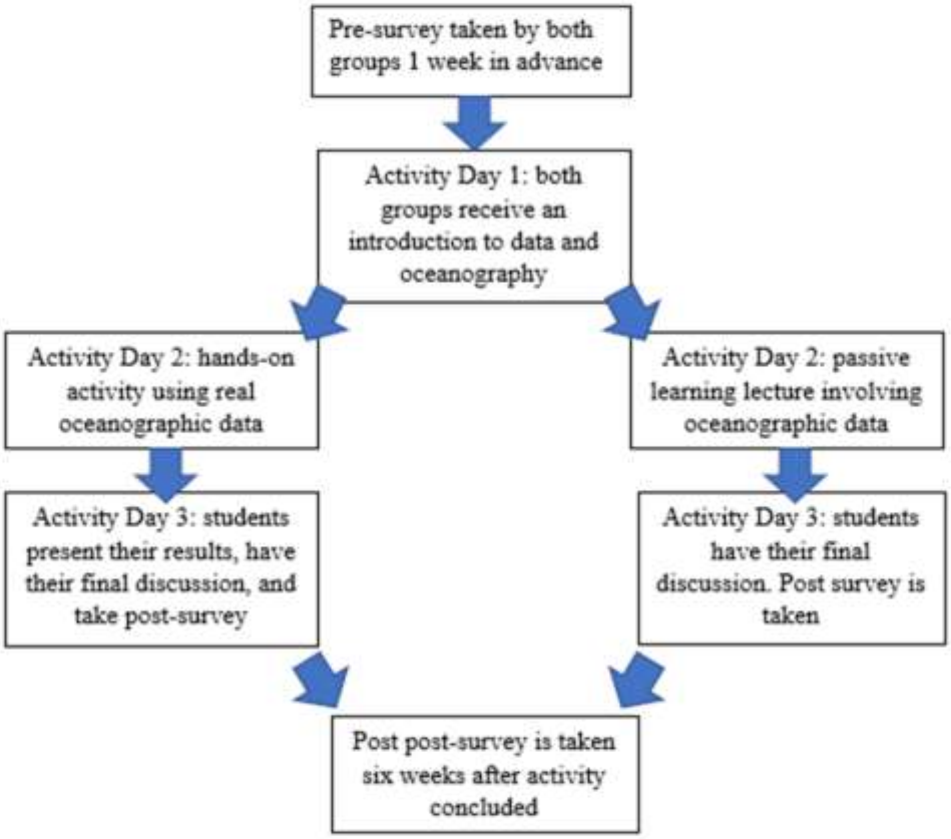

Figure 4.1: Experimental Design

4.3.2 Module Design

This curriculum module consists of four lessons, and was designed according to the Kemp Instructional Design Model (Akbulut, 2007). Lessons Two and Three utilize the Jigsaw Cooperative Learning Technique (Tanner, Chatman, & Allen, 2003). To identify instructional challenges and relevant goals, this study reviewed scientific literature, interviewed high school science teachers from a variety of subjects, and identified links to Next Generation Science Standards (NGSS). These methods identified that for a data-focused module to be successful, it would need detailed background and supporting resources for teachers as well as activities that utilize canned data to build data literacy, before beginning students in extensions utilizing near real-time data. The ELG was taught utilizing this module, which was revised following classroom implementation and teacher feedback. The full curriculum in its final, revised format can be found at https://ceoas.oregonstate.edu/ships/rcrv/outreach/.

4.3.3 Study Participants

This study took place at Taft High School, which is located in Lincoln, City, Oregon and is a part of the Lincoln County School District. The Lincoln County School District was selected because it frequently partners with Oregon Sea Grant (OSG) and Oregon State University (OSU) researchers. The teacher from Taft High who participated in this study had recently completed a professional development opportunity put on by OSG, where they experienced research efforts aboard the OSU research vessel *Oceanus*. During this time, the teacher gained first-hand knowledge about data collection methods and data analysis, and was able to apply that knowledge to support the creation, implementation, and subsequent revision of the educational module.

According to the Oregon Department of Education School Profile (2018), Taft high school currently serves 440 students in grades 9-12, with a student population that is 61% White, 27% Hispanic/Latino, 7% Multiracial, 2% Asian, 2% American Indian/Alaskan Native, 1% African American, and <1% Native Hawaiian/Pacific Islander. Taft High School has an economically disadvantaged measure of 62%, which reflects the percentage of students who are receiving free or reduced-priced lunches. On average, 29% of students at this school achieve proficiency in math, and 43% achieve proficiency in reading and the language arts. This research included four biology classes under the instruction of the same teacher. Ninety percent of students in the sample were in 9th grade, 8% in 10th grade, 1% in 11th grade and <1% in 12th grade. One hundred and thirty-seven students participated in this project. All three surveys (i.e., pre, post, post-post) were completed by 109 (ELG: n=53; PLG: n=56) students. To identify students while protecting their anonymity, each labeled their surveys with IDs consisting of their initials, birth month, and birth day.

4.3.4 Survey Design

The survey evaluated seven concepts. The first five; beliefs about science, data literacy, factual knowledge of science, behavior toward science, and perceived knowledge of science, were measured on a continuous scale of 1) strongly disagree, 2) moderately disagree, 3) slightly disagree, 4) neither disagree or agree, 5) slightly agree, 6) moderately agree, 7) strongly agree, and 8) I don’t know (Likert, 1932). Attitudes toward science and emotions toward science were measured using 12 statements on a semantic differential scale from 1-4 (Heise, 1970). In this section, students were asked to indicate how they felt about science in general and learning science in school, using four descriptive scales (harmful to beneficial, bad to good, negative to positive, dislike to like).

4.3.5 Analysis

Survey data were analyzed using the quantitative software Statistical Program for the Social Sciences (SPSS). A reliability analysis was conducted on the variables DL, attitudes toward science, beliefs about science, emotions toward science, and behavior toward science indices to determine the reliability (or the extent of how consistent an index is at measuring a concept) of each set of items within each index. The internal consistency is represented by a coefficient known as Cronbach's Alpha (Cortina, 1993). Factual knowledge of science and perceived knowledge of science were not included in the reliability analysis, as they were measured by only 1 item each. After conducting the reliability analysis, the non-parametric, rank-based Friedman's Test was used to assess change within each group (i.e., ELG, PLG) over time. The non-parametric Mann-Whitney U Test, which tests for differences between two groups on a single, ordinal variable with no specific distribution (Mann & Whitney, 1947) was used to assess differences between groups at each point in time (pre, post, and post-post). Due to multiple tests being run on the same set of data over multiple points in time, a significance level of $p < .03$ was adopted based on the Bonferroni correction procedure, to reduce the risk of obtaining type 1 errors (where a non-significant result is mislabeled as significant).

4.4 Results

4.4.1 Data Literacy

Originally, DL was measured by 5 items. However, the reliability analysis showed that Cronbach's alpha for the pre-survey would rise to .68 with the removal of one variable (see the remaining four variables in Table 4.2). After the removal of the variable “I do not know how researchers find answers from their data,” the post and post-post reliability analysis supported the combination of variables into the DL index with Cronbach alphas of .76 and .79 respectively.

The Friedman’s test showed there was a significant increase in DL means from pre to post within the PLG (Friedman’s Stat = 9.77; $p < .01$; $\eta_p^2=.11$), followed by a slight decrease from post to post-post, remaining slightly higher than the original pre-mean (see Table 4.1). The positive shift in means is representative of a higher level of DL, while a negative shift in means is representative of a lower level of DL. Following the procedure described in Cohen, Cohen, West, and Aiken (2003), where the measurements of partial eta-squared effect size statistic are considered to be .01 (small), .09 (medium), and .25 (large), the PLG results represent a medium effect size. Although the ELG also increased in mean from pre to post, it was not a significant change (Friedman’s Stat = 5.01, $p = .81$, $\eta_p^2 = .05$). A Mann Whitney-U test showed no significant difference in the mean DL between the ELG and PLG, with *p* values of .78, .58, and .85 respectively.

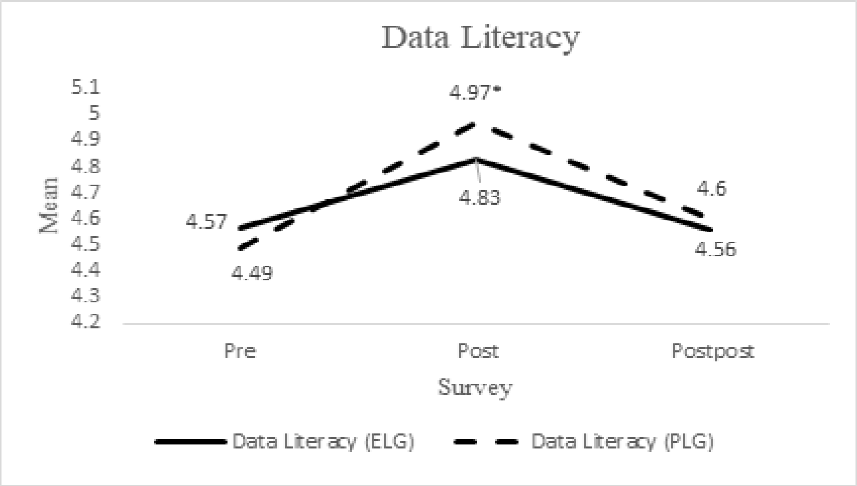

Figure 4.2: Change in means between the ELG and the PLG for data literacy index

Table 4.1: Results of Friedman’s Test on survey variables for ELG and PLG

Variable Tested	Pre-Mean	Post-Mean	Post Post-Mean	Friedman's Stat	*p*-value	η_P^2
Data Literacy (ELG)	4.57	4.83	4.56	5.01	.81	.05
Data Literacy (PLG)*	4.49	4.97	4.60	9.77	<.01	.11
Attitudes toward Science (ELG)	3.34	3.57	3.47	5.70	.05	.04
Attitudes toward Science (PLG)*	3.55	3.91	3.66	11.30	<.01	.16
Beliefs about Science (ELG)	4.79	4.91	4.76	2.83	.24	.03
Beliefs about Science (PLG)*	4.93	5.31	4.93	22.0	<.01	.16
Perceived Knowledge (ELG)	4.30	4.78	4.17	6.50	.04	.08
Perceived Knowledge (PLG)	4.33	4.49	4.84	3.15	.21	.10
Factual Knowledge (ELG)	4.90	5.13	5.40	3.54	.17	.08
Factual Knowledge (PLG)	5.23	5.30	5.37	0.03	.97	<.01
Emotions toward Science (ELG)	3.70	3.78	3.59	3.65	.05	.05
Emotions toward Science (PLG)	3.89	4.01	3.78	4.17	.04	.04

*****Significant after adjusting for the Bonferroni correction of $p<0.03$

Table 4.2. Reliability analysis of pre-survey attitudes toward science, beliefs about science, emotions toward science, behavior toward science, and data literacy

Variables	Mean (M)	Std dev. (SD)	Item total correlation	Alpha (α) if deleted	Cronbach alpha (α)
General Attitudes Toward Science[1]					.92
Indicate on each of the following scales how you feel about science in general (dislike to like).	3.14	1.13	.77	.90	
Indicate on each of the following scales how you feel about science in general (bad to good).	3.53	1.17	.75	.90	
Indicate on each of the following scales how you feel about science in general (negative to positive).	3.52	1.08	.76	.90	
Indicate on each of the following scales how you feel about science in general (harmful to beneficial).	3.76	1.11	.57	.92	
Indicate on each of the following scales how you feel about learning science in school (dislike to like).	3.02	1.22	.72	.91	
Indicate on each of the following scales how you feel about learning science in school (bad to good).	3.36	1.15	.80	.90	
Indicate on each of the following scales how you feel about learning science in school (negative to positive).	3.37	1.17	.85	.90	
Indicate on each of the following scales how you feel about learning science in school (harmful to beneficial).	3.70	1.10	.59	.92	
Beliefs about Science[2]					.78
Science is the most interesting school subject.	4.33	1.72	.62	.73	
I do not want to study science in college.	4.03	2.00	.44	.78	
Science is fun.	4.81	1.78	.68	.71	
It would be cool to be a scientist.	4.22	1.78	.59	.74	
I enjoy learning through hands-on activities, such as field trips.	6.43	.96	.39	.78	
Science is useful for everyone to learn.	5.37	1.37	.52	.75	
Data Literacy[2]					.68
I am comfortable working with data in class.	5.47	1.42	.54	.56	
I understand how data are collected by researchers.	4.39	1.38	.34	.68	
I am comfortable with finding patterns in data.	4.74	1.54	.53	.57	
I am comfortable figuring out challenging problems with data sets	3.73	1.64	.45	.62	
Behavior toward Science[2]	4.89	1.51	.39		.57
I can apply what I learn in science class to the real world.	4.53	1.64	.39		
I look for scientific evidence before making decisions about important issues.					
Emotions toward Science[1]					.92
Please indicate on each of the following scales how you would react to learning about marine science, for example, marine mammals like whales or dolphins. (dislike to like).	3.67	1.26	.81	.89	
Please indicate on each of the following scales how you would react to learning about marine science, for example, marine mammals like whales or dolphins (bad to good).	3.72	1.14	.85	.88	
Please indicate on each of the following scales how you would react to learning about marine science, for example, marine mammals like whales or dolphins. (negative to positive).	3.67	1.18	.86	.87	
Please indicate on each of the following scales how you would react to learning about marine science, for example, marine mammals like whales or dolphins. (harmful to beneficial).	3.90	1.14	.71	.92	

1. Variables measured on a 4-point scale.
2. Variables measured on a 7-point scale of 1 "strongly disagree" to 7 "strongly agree."

Table 4.3. Reliability analysis of post-survey attitudes toward science, beliefs about science, emotions toward science, behavior toward science, and data literacy

Variables	Mean (M)	Std dev. (SD)	Item total correlation	Alpha (α) if deleted	Cronbach alpha (α)
General Attitudes Toward Science[1]					.92
Indicate on each of the following scales how you feel about science in general (dislike to like).	3.40	1.13	.70	.91	
Indicate on each of the following scales how you feel about science in general (bad to good).	3.78	0.98	.74	.91	
Indicate on each of the following scales how you feel about science in general (negative to positive).	3.77	1.00	.81	.91	
Indicate on each of the following scales how you feel about science in general (harmful to beneficial).	4.08	1.09	.66	.92	
Indicate on each of the following scales how you feel about learning science in school (dislike to like)	3.31	1.13	.71	.91	
Indicate on each of the following scales how you feel about learning science in school (bad to good).	3.57	0.97	.80	.91	
Indicate on each of the following scales how you feel about learning science in school (negative to positive).	3.73	1.00	.79	.91	
Indicate on each of the following scales how you feel about learning science in school (harmful to beneficial).	3.93	1.04	.69	.91	
Beliefs about Science[2]					.86
Science is the most interesting school subject.	4.71	1.51	.77	.82	
I do not want to study science in college.	3.91	1.77	.62	.85	
Science is fun.	5.18	1.56	.84	.80	
It would be cool to be a scientist.	4.72	1.68	.68	.83	
I enjoy learning through hands-on activities, such as field trips.	6.31	1.27	.56	.85	
Science is useful for everyone to learn.	5.62	1.30	.47	.87	
Data Literacy[2]					.76
I am comfortable working with data in class.	5.08	1.39	.57	.69	
I understand how data are collected by researchers.	5.63	1.18	.53	.68	
I am comfortable with finding patterns in data.	5.02	1.44	.66	.57	
I am comfortable figuring out challenging problems with data sets.	3.78	1.70	.50	.62	.53
Behavior toward Science[2]	5.72	1.11	.37		
I can apply what I learn in science class to the real world.	4.75	1.51	.37		
I look for scientific evidence before making decisions about important issues.					
Emotions toward Science[2]					.89
Please indicate on each of the following scales how you would react to learning about marine science, for example, marine mammals like whales or dolphins. (dislike to like).	3.80	1.23	.75	.86	
Please indicate on each of the following scales how you would react to learning about marine science, for example, marine mammals like whales or dolphins (bad to good).	3.85	1.06	.83	.83	
Please indicate on each of the following scales how you would react to learning about marine science, for example, marine mammals like whales or dolphins. (negative to positive).	3.98	1.00	.82	.83	
Please indicate on each of the following scales how you would react to learning about marine science, for example, marine mammals like whales or dolphins. (harmful to beneficial).	3.90	1.10	.63	.90	

1. Variables measured on a 4-point scale.
2. Variables measured on a 7-point scale of 1 "strongly disagree" to 7 "strongly agree."

Table 4.4. Reliability analysis of post post-survey attitudes toward science, beliefs about science, emotions toward science, behavior toward science, and data literacy

Variables	Mean (M)	Std dev. (SD)	Item total correlation	Alpha (α) if deleted	Cronbach alpha (α)
General Attitudes Toward Science[1]					.92
Indicate on each of the following scales how you feel about science in general (dislike to like).	3.26	1.07	.78	.94	
Indicate on each of the following scales how you feel about science in general (bad to good).	3.61	1.03	.83	.94	
Indicate on each of the following scales how you feel about science in general (negative to positive).	3.65	1.08	.83	.94	
Indicate on each of the following scales how you feel about science in general (harmful to beneficial).	3.80	1.09	.67	.94	
Indicate on each of the following scales how you feel about learning science in school (dislike to like)	3.26	1.07	.78	.94	
Indicate on each of the following scales how you feel about learning science in school (bad to good).	3.61	1.04	.88	.93	
Indicate on each of the following scales how you feel about learning science in school (negative to positive).	3.67	1.07	.88	.93	
Indicate on each of the following scales how you feel about learning science in school (harmful to beneficial).	3.82	0.98	.73	.94	
Beliefs about Science[2]					.77
Science is the most interesting school subject.	4.43	1.66	.57	.72	
I do not want to study science in college.	3.87	1.61	.54	.73	
Science is fun.	4.98	1.57	.68	.70	
It would be cool to be a scientist.	4.65	1.50	.59	.72	
I enjoy learning through hands-on activities, such as field trips.	6.17	1.27	.27	.79	
Science is useful for everyone to learn.	5.52	1.34	.43	.76	
Data Literacy[2]					.79
I am comfortable working with data in class.	5.00	1.52	.58	.76	
I understand how data are collected by researchers.	4.99	1.25	.57	.76	
I am comfortable with finding patterns in data.	4.82	1.57	.63	.74	
I am comfortable figuring out challenging problems with data sets.	3.50	1.62	.58	.76	
Behavior toward Science[2]					.61
I can apply what I learn in science class to the real world.	5.44	1.35	.45		
I look for scientific evidence before making decisions about important issues.	4.67	1.53	.45		
Emotions toward Science[2]					.92
Please indicate on each of the following scales how you would react to learning about marine science, for example, marine mammals like whales or dolphins. (dislike to like).	3.64	1.18	.80	.86	
Please indicate on each of the following scales how you would react to learning about marine science, for example, marine mammals like whales or dolphins (bad to good).	3.70	1.09	.90	.83	
Please indicate on each of the following scales how you would react to learning about marine science, for example, marine mammals like whales or dolphins. (negative to positive).	3.81	1.07	.90	.83	
Please indicate on each of the following scales how you would react to learning about marine science, for example, marine mammals like whales or dolphins. (harmful to beneficial).	3.76	1.07	.71	.90	

1 Variables measured on a 4-point scale.

2 Variables measured on a 7-point scale of 1 "strongly disagree" to 7 "strongly agree.

4.4.2 Attitudes toward Science

The combination of items in the attitudes toward science index was supported by reliability analysis, where the pre, post, and post-post Cronbach alpha was consistently .92. In the post-post reliability analysis, Cronbach alpha could be minimally improved with the removal of any item, yet this would have a slight negative on alphas of the pre and post reliability analysis. Due to the minimal improvement and minimal decline that would result in removing any of these items, they were kept in the index.

Similar to the DL index, the Friedman's test showed there was a significant increase in attitudes toward science means from pre to post within the PLG (Friedman's Stat = 11.3, $p < .01$, $\eta_p^2 = .16$), followed by a decrease from post to post-post that remained slightly higher than the pre-mean (see Table 4.1). The effect size for these changes ($\eta_p^2 = .16$) is considered between medium and large. The ELG experienced a similar pattern of an increase in mean from pre to post, followed by a slight decrease from post to post-post, none of which were statistically significant (Friedman's Stat = 5.70, $p = .50$, $\eta_p^2 =.04$). However, the effect size for the ELG is considered between small and medium, at .04. The positive shift in means is representative of a more positive attitude toward science, while the negative shift does not necessarily represent a negative attitude, but returns to a less positive attitude. A Mann Whitney U test indicated that the mean difference in attitudes toward science between the ELG and PLG was significant on the post survey (Test Statistic = 2.18, $p = .03$, $r_{pb} = .27$). The effect size for this change is considered to be medium.

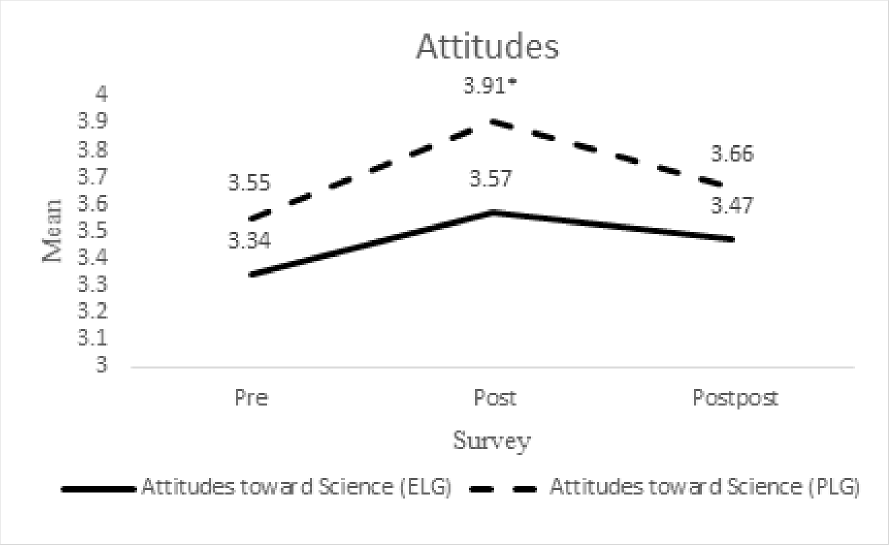

Figure 4.3: Change in means between the ELG and the PLG for the attitude index

4.4.3 Beliefs about Science

Originally measured by 8 items, the reliability analysis showed that Cronbach's Alpha would improve to .78 with the removal of the items "I do not enjoy science learning through lectures with note taking" and "I would be okay with getting a C or lower grade in my science class." The post and post-post reliability analysis further supported the combination of statements in the Beliefs index, with Cronbach alphas of .86 and .77, respectively. In the post reliability analysis, Cronbach alpha could have also been minimally improved with the removal of the item "science is useful for everyone to learn," yet this too would have a slight negative effect on alphas for the pre and post post-reliability analysis. Due to the minimal improvement and minimal decline that would result in removing this item, it was retained in the index.

The results from the Friedman's Test showed a significant within-group change in beliefs toward science from pre to post for the PLG (Friedman's Stat=22.0, p<.001, η_p^2=.16), and then a reversion to the original pre-mean (4.93) from post to post-post. The effect size of this change is considered to be between medium and large. The ELG exhibited the same trend, but was not significant (Friedman's Stat=2.83, p=.24, η_p^2=.03). The positive shift in means is representative of more positive beliefs about science, while the negative shift does not necessarily represent negative beliefs about science, but indicates less positive beliefs. A Mann Whitney U Test indicated a significant difference in means between the ELG and PLG beliefs about science for the post survey, with (Test Statistic = 3.04, p <.01, r_{pb} = .23). The point biserial correlation of .23 is considered between small and medium effect size.

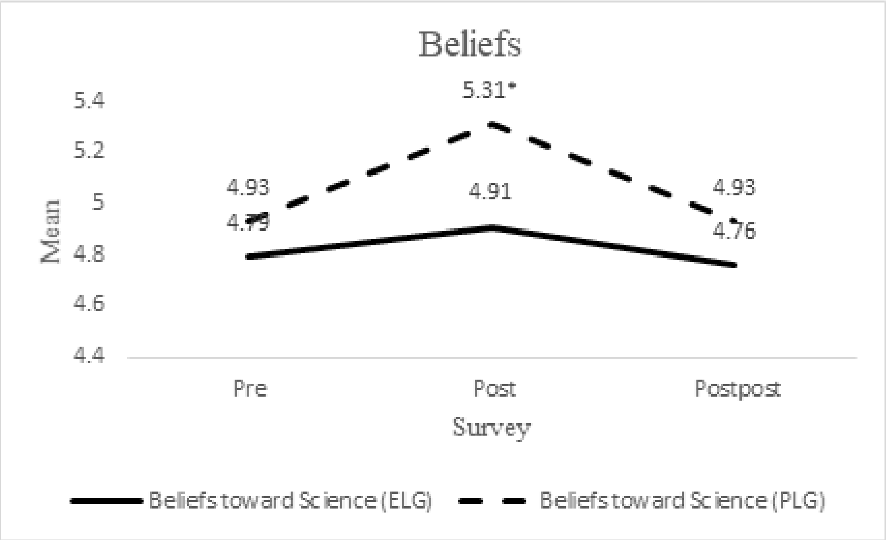

Figure 4.4: Change in means between the ELG and the PLG for the beliefs index.

4.4.4 Other Indices: Emotions, Behavior toward Science, Factual Knowledge, Perceived Knowledge

The survey originally tested for emotions toward science, which was supported by a reliability analysis resulting in Cronbach alphas of .92, .89, and .92 across the three points in time (Tables 4.2, 4.3, 4.4). Behavior toward science (which refers to actions informed by science) was not supported by a reliability analysis, with Cronbach alphas of .57, .53, and .61, thus was not included in further analysis (Tables 4.2, 4.3, 4.4). The survey also tested for factual knowledge of science and perceived knowledge of science, but these both consisted of single items so reliability could not be tested. Emotions, factual knowledge, and perceived knowledge exhibited similar patterns, as all increased from pre to post, and then declined from post to post-post except factual knowledge. Within the ELG and PLG, Friedman's test found no statistically significant change for emotions, factual knowledge, or perceived knowledge (Table 4.1). Mann Whitney-U tests did not indicate any significant differences at each point in time for emotions (p=.65, p=.30, p=.22), factual knowledge (p =.59, p =.59, p =.89), and perceived knowledge (p=.08, p=.18,p=.08) between the ELG and PLG as well.

4.5 Discussion

This research intended to measure the impacts of experiential learning utilizing a contextualized, oceanographic data-focused module on high school students. Previous research showed a potential link between experiential learning with authentic data and positive impacts, such as better engagement and critical thinking skills (Kjelvik & Schultheis, 2019; Gould et al., 2014 ; Ucar & Trundle, 2011, Kerlin et al., 2010) . However, the lack of significant results originating from the ELG does not necessarily negate a link between them. Instead, the results highlight a set of underlying issues that must be addressed including a lack of preexisting data literacy, short instruction time, and the ELG students potentially recognizing their self-perceptions of knowledge may not be as accurate as originally thought.

The first issue is a lack of pre-existing DL skills in many students. Per the NGSS, students entering the 9th grade should have already built their foundation in graphing skills and basic data analysis ("Read the Standards | Next Generation Science Standards"). During the design process of the module, the participating teacher suggested expanding the module from two to three days, as they thought students would need additional time. While three days was originally considered to be a potentially adequate period of instruction time, once classroom instruction began, it was clear that the existing level of student comfort in graphing and interpreting results in ELG students was minimal.

The lack of existing skills in these students caused a delay in the progression of activities in the learning module, resulting in the omission of the activity incorporating near real-time data, which may have affected post-survey results. The majority of instructional time for the ELG was spent working with students on building basic skills such as graphing, reading sets of data, and identifying trends. The existing lack of DL skills in these students could indicate a lack of focus on developing DL skills at the middle school level – and highlight the challenges high school teachers often face when attempting to utilize data in their classrooms.

Although the ELG did not experience significant change over time in DL, attitudes, or beliefs despite their hands-on experience, these results can potentially be connected to the theories of "robust and shallow learning" (Baker, Gowda, Corbett, & Ocumpaugh, 2012; Chin & Brown, 2000). The ultimate goal of a lesson is that students experience what is known as robust learning, that is, learning that leads the student to be able to transfer their knowledge, think critically, and that prepares them for future learning (Baker, Gowda, Corbett, & Ocumpaugh, 2012; Chin & Brown, 2000). In contrast, shallow learning occurs when students concentrate more on memorization of content, focusing on facts without being able to make arguments, apply information to new contexts, or think critically (Baker, Gowda, Corbett, & Ocumpaugh, 2012; Chin & Brown, 2000). Shallow learning can occur when students are not challenged to think critically or engaged in related hands-on activities, and can lead to students perceiving their knowledge and skills as higher than they actually are (Baker, Gowda, Corbett, & Ocumpaugh, 2012; Chin & Brown, 2000).

The act of perceiving one's knowledge as higher than it actually is called the Dunning-Kruger effect (Wanner, 2015). This effect means self-reports of understanding are not always representative of true understanding. In fact, although the PLG considered their DL to be stronger in the post survey, graphical interpretation skills were assessed in a brief qualitative portion of the student survey and no distinguishable difference in the DL from pre to post-post survey was observed. This portrays that the PLG most likely experienced shallow learning that led to them perceive their skills as higher than they actually were. The ELG may have had the potential for robust learning, but due to the lack of existing skills observed during classroom instruction and the fast pace, may have felt overwhelmed.

It is possible that because the PLG was not challenged in the same way as the ELG, they experienced "shallow learning," or their understanding of marine science research and its importance remained at a surface level. The ELG group, while poorly prepared, was challenged to think critically and work hands-on with the data. Although also speculative, it is possible that the ELG understood more about working with data, but the instruction time was not long enough to build up the lacking foundational skills *and* introduce the new information and skills needed to produce statistically significant results.

To further explore why the PLG may have been the only group to experience significant results, D'Mello and Graesser (2012) concluded that in the learning process, students will face barriers that upset their "cognitive equilibrium." Students can successfully restore equilibrium by reflection and problem solving, which eventually can lead to robust learning, while students who cannot overcome the barrier eventually may become disengaged or bored. The PLG cognitive equilibrium was likely never interrupted, meaning they were not tasked with having to work to restore the equilibrium and achieve robust learning. However, it should be noted that the significant results for the PLG were actually quite minimal in terms of their change. For example, the PLG significant mean change for the beliefs index (pre=4.93, post=5.31) represents a slight increase from the continuous scale options of “4=neither disagree or agree,” to “5=slight agree.” A similar pattern is reflected for all other significant results both for the within group change and the between group change.

Finally, it was clear during classroom implementation that instruction time needed to be much more substantial than three days to accomplish the identified educational goals. The module as it was originally written, did not result in the robust learning necessary to increase of DL, in addition to affecting positive attitudes and beliefs. Ideally, students need better preparation at each educational level, as well as extended, contextualized data-focused learning rather than one-off activities or a handful of days of learning (Andersen, Humlum, & Nandrup, 2016). Research shows that although an increase in instructional time in school does increase learning, it also depends on the quality of instruction, the classroom environment, and the time required for student processing of knowledge (Rivkin and Schiman, 2015). In Oregon, students have the lowest instructional time for elementary science in the United States of 1.9 hours per week (Blank, 2012). This low instructional time can potentially be impacting Oregon students as progress through their education, as they are not receiving the foundational science concepts and skills as they should be (Blank, 2012).

4.6 Lessons Learned

Two important lessons were learned throughout the design and implementation of this module. First, a word of caution for those designing classroom-based DL research regarding state educational standards. As Oregon adopted NGSS in 2014, the design of this module operated under the assumption that students would be prepared according to NGSS performance expectations. However, the mandatory assessment test for science students to take in grades five, eight, and at the high school level was not finalized until the 2018-2019 school year (Oregon Department of Education, 2018). This highlights an important step in the lesson design process – assuring what standards students align with to properly form learning outcomes.

Additionally, this research highlighted a need for continued research on instructional techniques for DL as the results of this study exemplify how using data in the classroom can potentially backfire. Without rigorous best practices to utilize, fostering DL may be a process of trial and error, which can potentially lead to students leaving the classroom with a false sense of confidence in their knowledge and abilities.

4.7 Final Thoughts

Although the results of this study did not support the notion that contextualized, data-focused, experiential learning could positively impact high school students' DL, attitudes, and beliefs toward science, the results can still potentially inform the gaps in the field of DL instructional techniques. The results of this research highlight a series of underlying challenges that should be addressed to support future research efforts, as well support a more data-literate and engaged future workforce. Teachers need to focus on hands-on, experiential learning activities to support robust learning that is needed to increase DL skills, and foster positive attitudes and beliefs about science. In addition, educators should assess the existing data literacy skills of their students before exposing them to new DL concepts. This ensures that a planned module can progress smoothly, and informs the educators of what gaps in student knowledge exist. Finally, ensuring that instructional time of DL concepts is extended for a longer period than a three-day activity can potentially help support DL skills, yet more research is needed on this topic. Neglecting to incorporate these sorts of activities and teaching methods could potentially result in shallow learning, which could in turn lead students to perceive their knowledge about a subject as higher than their demonstrable skills, negatively impacting them as they move forward through their academic career.

4.8 Opportunities for Future Research

Continuing research into the DL of students is critical, but future work should incorporate larger sample sizes, and include multiple schools and/or districts. This area of study could also benefit from additional research on DL skills of middle school students, where the foundations of graphing and analysis skills should be built. Additionally, future work should be conducted on hands-on, data-focused learning that evaluates both perceived knowledge and demonstrated knowledge, over a longer time period of time. Using surveys to track student changes throughout an entire school year, or even across multiple years would provide a better overall view of the development of DL, beliefs about science, and attitudes toward science in secondary students.

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Chapter 5

Conclusions

5.1. Overview

Data literacy (DL) is becoming a necessary skill, not just for those working in the technology sector or the business sector, but also for resource managers who need to understand data to inform their management practices and policy makers who need to understand data in order to address the complex issues they must tackle. Data literacy is needed at the local, state and federal levels, to help address key issues, be it economic or ecological. One of the best tools we have as a society to combat issues such as climate change, overfishing, or pollution is data-driven decision making.

The more informed the general public is, the more potential they have to be empowered to make changes in their own lives and support data-driven change in society. Through improved education and outreach practices, engagement and DL skills can be increased for all stakeholder groups in the Data Stream, otherwise known as facilitating the flow of data from researcher to teacher to student. However, inherent to the Data Stream are many challenges preventing not only the efficient transfer of the data itself but the effective transfer of knowledge associated with the data. This research project was designed to identify ways to best facilitate the flow of the Data Stream, to support a data literate populace and workforce equipped to deal with even the most challenging issues.

5.2 Phase One Findings

In Phase one of this research, interviews were conducted with researchers, teachers, and professionals such as outreach specialists and professional development providers. Common themes regarding barriers were identified by all stakeholder groups involved in interviews and included a lack of time, lack of support, and lack of knowledge. To overcome these barriers, stakeholders need adequate and effective resources, such as high-quality PD, time saving materials, and an easily navigable data portal to deliver data that are usable to researchers, teachers, and their students. These needs were reiterated in a review of 8 years-worth of surveys from data-focused teacher workshops, aimed at incorporating real data into classrooms. These findings were also supported by a review of existing data-portals, in addition to a teacher review of data portals.

Through interviews, researchers expressed the need for their own PD that includes effective communication techniques, as well as instruction on altering communication styles to suit a variety of audiences. For teachers, PD should help increase comfort in working with data, use examples that provide step by step instructions with lesson plans, and provide time for collaboration with researchers and other teachers. Time saving materials for both groups are another useful tool, with teachers identifying a need for relevant, data-focused curriculum and activities that include thorough instructions and utilize static (“canned”) and/or real-time data. Additionally, easy to use web portals with minimal clicks that provide tutorials or instructions for navigating the website, a help section, and a place to access educational materials is beneficial for both teacher and student engagement.

Through this project, an obvious disconnect became apparent between researchers and educators. While participating researchers expressed frustration that teachers were not more enthusiastic about using their data, teachers expressed equal amounts of frustration that researchers are not delivering data in a way that made sense to them and their students. To help bridge this disconnect, programs like the RCRV project can serve as liaisons between the stakeholder groups, supporting communication and collaboration, fostering increased skill building and confidence, and providing time saving resources that are needed for success.

5.3 Phase Two Findings

Phase two of this project sought to put the lessons learned in phase one into practice through the creation and testing of a data-focused educational module for high school students. This portion of the project centered on providing an experiential learning group (ELG) with hands-on, data-focused learning, and comparing outcomes to those of a passive learning group (PLG) who participated in a more passive, lecture and note style of learning. The results from phase one highlighted the need for data to be in a simple format for use, consistent, and relevant to students. Relevancy was a key concept teachers identified as important when it came to working with data in the classroom, so students could relate the data to their own lives. Teachers also expressed that students sometimes did not have the existing background or DL skills needed to fully engage in an activity. For these reasons, the data-focused educational module that was developed utilized canned oceanographic data collected off the Oregon Coast to build DL, then provided an extension activity which incorporated near real-time data from the Oregon Coast. Originally, it was hypothesized that the ELG would have the greatest change in means, while the PLG would have resulted in less significant changes.

Each group participated in three days of instruction and showed positive within-group increases for all variables tested in the post survey. Although students from the ELG showed increases from pre to post, a Friedman's test showed that none of the within group changes were statistically significant. It was the PLG that showed significant improvements in all three variables from pre to post. Despite the lack of statistically significant responses in ELG students, their teacher had this to say in her post-post reflection, written six weeks after the module was completed, "the activity seemed to impact my students' understandings of data and they don't seem to be as intimidated by numbers and graphing now. I think initially some of their attitudes towards science may have shifted…. literacy is a process and I think the activities enhanced their understanding of how, why, and what scientists do."

From observation, the experiential learning group showed a surprising lack of existing DL skills. Students struggled with basic graphing and mapping concepts, which meant the original timeline set for the activities would not be adequate. Rather than rush students through the activity so they could move on to the extension using near real-time data, it was decided that it would be more valuable to spend additional time solidifying the DL skills that these students lacked. Because of this, students were not able to work with real-time data, but were given time to allow for individual and group processing, sense-making, and to communicate their results.

While the lack of significant results stemming from the ELG was somewhat unexpected, the implementation of this education module did reveal what it is like to balance the various challenges teachers had expressed during interviews: the lack of DL in students, large classroom sizes, the struggle to make data relevant, and meet NGSS standards while attempting to implement experiential learning techniques.

The experience working with students in the classroom combined with feedback from the classroom teacher provided insight needed to improve the data-focused learning module. It was clear that instructional time needed to be increased, to support additional time building DL and allow for the completion of the near real-time data activity. Finally, encouraging students to actively participate in communicating their results by switching from a group discussion to a poster presentation, would allow them more robust opportunities to engage.

A review of the brief qualitative section of the student surveys that required them to interpret graphs did not show any major changes in demonstrable DL. This result led to the conclusion that the PLG were most likely over-estimating their DL skills as more adept than they actually are, a common sign of "shallow learning." Shallow learning can potentially be just as troublesome as no learning, as it gives students a surface level view of a topic or issue, and promotes the false perception of full understanding (Baker, Gowda, Corbett, & Ocumpaugh, 2012).

5.4 Final Thoughts

Ultimately, there is no one stakeholder group that "stalls" the Data Stream. Researchers struggle to communicate their data, teachers struggle with understanding how to utilize that data effectively, and students struggle to make sense of the data. Each group faces their own unique set of challenges which requires effort for the Data Stream to be effective. Data-providers, such as the RCRV project, can provide effective and useful resources to assist in the transfer of data. There is no one size fits all answer for how to best facilitate an unobstructed Data Stream, but information collected over the course of this project can be used to identify potential barriers to success and opportunities for collaboration and improvement of communication. The culmination of these two phases will hopefully provide future research with information they need to successfully support DL throughout the Data Stream.

5.5 Opportunities for Future Research

While this research identified potentially useful resources for high school teachers and their students, there are areas of future research that should be explored. Exploring data-focused learning at each level of K-12 is important for constructing best practices for instruction, in order to support DL across a student’s academic career, Additionally, conducting research to take into account how to support the DL of students from a variety of backgrounds is vital to ensuring the future workforce is diverse, representative, and adequately prepared.

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APPENDICES

APPENDIX A: A Sea of Data Learning Module

A SEA OF DATA

A high school learning module focused on oceanography, research and exploring marine science data

Oregon State University

Sea Grant Oregon

NSF

R/V TAANI OREGON STATE UNIVERSITY

TABLE OF CONTENTS

Timeframe: 6 fifty-minute periods

8 fifty-minute periods with near real-time data extension

Target Audience: 9th-12th Grade

Curriculum Overview

In the following lessons, students will build their science and data literacy skills while gaining foundational knowledge about marine science research. They will investigate sets of marine science data collected on Oregon State University research vessels and explore real oceanographic data being collected off the Oregon Coast. In the first lesson, students will build their foundation in understanding of oceanographic concepts by learning about the who, what, when, where and why of local marine science research. In Lesson 2, students will be introduced to more practical applications of oceanographic research by exploring 3 data sets collected off of the Oregon Coast. Using the Jigsaw Cooperative Learning Technique, students will work in small groups and participate in a specific data-focused task that will include reading and analyzing data, as well as employing graphing and mapping skills. Students will then practice science communication skills and demonstrate their understanding of the content by presenting their findings to their fellow students in a poster format. If teachers have access to the required technology and additional time, there is an extension lesson via the Northwest Association of Networked Ocean Observing Systems (NANOOS). This lesson allows students to not only explore a near real-time data portal, but connect what they have learned about water quality, plankton, upwelling and the Oregon Coast by using an interactive data portal. This lesson requires access to an internet-enabled computer lab or Google Chromebooks, and includes a lab demonstration of upwelling. Finally, students will reflect on key concepts learned through small group discussions and with their larger class.

Objectives

Students will:

- Learn why understanding and evaluating data is an important skill in today's world
- Build a foundation in oceanographic knowledge by learning about the who, what, when, where and why of marine science research and data
- Learn about a variety of techniques used to collect marine science data
- Evaluate sets of real oceanographic data collected off of the Oregon Coast
- Synthesize results and communicate information with their classmates
- Explore real-time marine science data

Essential Questions

- What are the disciplines of marine science research?
- Why is marine science research important?
- Why is being able to interpret data important?
- What can marine science data tell us?
- How are different parts of an ocean ecosystem related?

Next Generation Science Standards

PERFORMANCE EXPECTATIONS

- HS-LS2-1 Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales
- HS-LS2-2 Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales

- HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem
- HS-LS4-5. Evaluate the evidence supporting claims that changes in environmental conditions may result in (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species

DISCIPLINARY CORE IDEAS

- LS2.C. Ecosystem Dynamics, Functioning and Resilience
- LS4.D. Biodiversity and Humans

SCIENCE AND ENGINEERING PRACTICES

- Using Mathematics and Computational Thinking

CROSSCUTTING CONCEPTS

- Cause and Effect (LS45)

A SEA OF DATA: Lesson 1

Timeframe: One 50-minute period

Target Audience: 9th-12th Grade

Suggested Materials:

- "A Sea of Data" PowerPoint.

Lesson Objectives

Students will:

- Understand the who, what, when, where and why of oceanographic research
- Understand why being able to interpret data in today's world is an important skill

Essential Questions

- Who are oceanographers? (Describing the diversity of people and jobs in the field).
- What are the different types of oceanographic research?
- When and where is oceanographic research conducted?
- Why is oceanographic research conducted and why should we care about how it used?
- Why is understanding data an important skill?

Setup

- Open PowerPoint
- Preload videos if Internet connectivity is an issue

Background Information:

Important Terms

- Anthropogenic – an issue that is directly caused by human action
- Upwelling – a seasonal process where wind blows surface water directing it away from shore, and cold, nutrient-dense deep water rises to the surface to replace it
- Regional Class Research Vessel – a moderately sized research vessel (199 feet maximum length) that conducts oceanographic research in a particular region

- Near real-time data: data that is collected and has some sort of quality control before being delivered to stakeholders, so that there is a slight delay
- Real-time data: data that is collected and beamed back to shore with almost no delay

The RCRV Project

The Regional Class Research Vessel (RCRV) Project at Oregon State University (OSU) has received grant funding from the National Science Foundation (NSF) to oversee the design and construction of three new RCRVs, the first of which (*R/V Taani)* will be operated by OSU. These RCRVs will have the capacity to produce real-time marine science data. The *R/V Taani* will allow OSU and other marine researchers to utilize many oceanographic tools and conduct a variety of research activities. This research will provide them, as well as educators and their students, an enormous amount of crucial, marine science data that can be used to educate the public, inform decision-making within our state and region, and potentially help address critical marine science issues.

Big Data & Data Literacy

Despite the accessibility of existing data, many students do not have the data literacy skills they need to properly understand data-activities in the classroom. In fact, only 21% of 16 to 24-year-olds consider themselves to be data literate (QLIK, 2018). Students often struggle with understanding what data is, understanding what to do with data, and understanding how data relates to them. This curriculum seeks to remedy these three challenges through a combination of lectures, discussions and data-focused, hands-on activities.

Big data refers to large sets of complex data. High school students today now have access to enormous amounts of data at the touch of a button. Data informs and drives nearly every aspect of society, including cell phone services, retail services, manufacturing and financial services, as well as scientific research (Jagadish et al., 2014). No matter what career path students may choose to pursue, understanding what data are, how data is collected, how it is used, and why it is important are crucial. Clearly, oceanographers are not the only data users and sources of data, but they provide an excellent example and contextualized learning opportunity for today's students.

Who are oceanographers?

Oceanographers are simply put – people who study the ocean! They are a diverse group of people who come from all over the globe and from a variety of backgrounds.

What do oceanographers do?

Oceanography, while generally known as being the study of the ocean, is broken down into four key areas (which themselves can be broken down into many, many specialties!) The four key areas are biological oceanography, chemical oceanography, physical oceanography and geological oceanography (US Department of Commerce-a).

Biological oceanographers, also known as marine biologists, study the plants and animals that live in the marine environment. Generally, their interests revolve around determining the numbers of organisms, and how these organisms change over time, interact with one another and interact with the world around them. To conduct their research, they often use field observations and experiments.

Chemical oceanographers, also known as marine chemists, study the chemistry of the ocean. They are interested in the composition of seawater, how the chemistry of the ocean varies over time and location, and the processes that affect the ocean's chemistry. Marine chemists work on a variety of issues, including pollution, ocean acidification, and how the chemistry of the ocean impacts and is impacted by organisms, currents, and other factors. They often use a combination of field work (taking water samples) and lab work (analyzing water samples).

Geological oceanographers, also known as marine geologists, explore the sea floor, and the processes that create the associated features (canyons, seamounts, etc.) Studying the seafloor allows marine geologists to "look back in time," and identify a variety of activities that happened to form the modern oceans, such as earthquakes, volcanic eruptions, spreading of the seafloor, and how ocean circulation and climate may have changed over time. Marine geologists often utilize sonar mapping of the seafloor and take large core samples of the sediment to analyze.

Physical oceanographers study the physical processes of the ocean including wave formation, movement of currents, erosion processes, transmission of light and sound through water, and the interaction of the ocean and the atmosphere. There are many ways for physical oceanographers to conduct their research. Some may use field research (using technology like gliders or hydrophones) while others may conduct lab research using a wave simulation pool or computer models.

Although defined separately, these fields are not isolated and frequently overlap in research. All oceanographers need to have background knowledge in each of the four areas but tend to be specialized in one of them.

When did oceanography become a science?

Historically, oceanography began as explorers started to map the oceans and identify specific phenomena, like currents. These efforts were motivated by everything from curiosity and wanting to expand personal knowledge, to economic incentives like finding a route to access goods from far-away lands. Benjamin Franklin made the first scientific study on the Gulf Stream, gave it its name, and published the first map of it in 1770. In 1873, the British vessel HMS Challenger left for what is considered to be the first true oceanographic expedition. The expedition lasted three years, and resulted in both a book and the declaration of oceanography as a discipline at the University of Edinburgh (McDaniel, Sprout, Boudreau, & Turgeon, 2012).

In modern times, oceanography is a wide-reaching scientific discipline. With oceanographers all over the world working for a variety of organizations such as universities (like Oregon State University) and government agencies (like the National Oceanic and Atmospheric Association [NOAA].

Where does oceanography happen?

Geographically, oceanography is a discipline that happens all over the world, from marine mammal biologists studying blue whales in New Zealand to studying ice melt in the Arctic.

Oregon has a unique coastline and oceanographic phenomena that make it a great place for oceanographic research! For example, we have “upwelling” off of our coast that results from Summertime winds blowing surface waters away from the shoreline, resulting in cold, nutrient dense water “welling up” from the deep. This nutrient dense water coming to the surface results in an explosion of biological activity, making the Oregon Coast a hot-spot for biodiversity which attracts researchers from all over the world. Additionally, Oregon provides insight into many large-scale issues. It is a place that has been hit by ocean warming and ocean acidification, a place with large storms and complex wave patterns that are being investigated as a potential source of marine renewable energy.

From a depth perspective, the majority of research has taken place in shallower waters. Recently, more effort has been made to explore and understand deeper areas of the ocean like the “Twilight Zone,” and the “Abyssal Zone.” The E/V Nautilus YouTube Page on deep sea exploration has many educational videos on this matter: https://www.youtube.com/channel/UC1KOOWHthbQVXH2kZue3_xA.

Why do we conduct oceanographic research?

“We know more about the dead seas of Mars than our own ocean.” – Jean-Michel Cousteau

The ocean is still a vastly unexplored place, with up to 95% of it still an unfamiliar place to humans. Yet, oceanographic research is not wandering the ocean for the sake of wandering. Research is crucial in assessing overall ocean health, identifying significant issues and finding solutions to address these issues. Human health is explicitly intertwined with ocean health, as it regulates our climate, provides us with oxygen and food provisions, and potentially holds new energy sources and important substances that could be developed into new drugs (US Department of Commerce-b). Oceanographic research can help provide insight into keeping the balance between our health and ocean health, inform policy-makers and managers on how to best manage our marine resources, and inspire and engage a new generation of future researchers.

Activity (Lecture):

[Slide 1: Introduction]

1) Introduce the curriculum to the class by sharing that they are going to be talking about data, through the lens of oceanographic research.

2) Begin by asking students to brainstorm with their table groups (or neighbors) what they think ‘big data’ are.

3) After defining it, have students discuss the importance of data in their daily lives, as well as the importance of “data literacy.”

    a. “*Does anyone know how data affects your daily life?”*

    b. “Why do you think it is important for people to be able to understand what data are and how data are used?”

[Slide 2: Big Data]

1) Once students have shared their ideas, discuss that not only does data drive most services and aspects of their daily lives, but data literacy is also an important skill to have in current and future careers,

Big Data: What is it & Why do you care?

→ Big Data:
1. Large amounts of available data
2. Can be challenging to find and use

→ You have more access to data than ever before
1. It's used in many of your daily activities
2. It's used in many modern careers

    a. “You live in a unique situation – you have almost unlimited access to huge amounts of data at the touch of a button. Whether you decide you want to be a scientist or not, most careers require candidates who are comfortable working with some sort of data.”

[Slide 3: The RCRV Project]

The RCRV Project

1) Explain that the Regional Class Research Vessel (RCRV) project at Oregon State University (OSU) is overseeing the design and construction of three new regional class research vessels.
2) Discuss that these vessels will have the ability to produce and beam back large amounts of real-time oceanographic data.
3) Finally, lead into the who, what, when, where and why of oceanography, so students have a strong foundation to move forward with data work in the following lessons.

[Slide 4: Who]

Who are oceanographers & What is oceanography?

1) Ask students what they think an oceanographer is.
2) Explain that oceanographers are those who study the ocean, and work in many different areas, on many specialized projects. Mention that oceanographers often go through many years of schooling to get into this field.
3) Ask students if any of them can name a famous oceanographer.
    a. Some examples are Jacques Cousteau and Sylvia Earle.

[Slide 4 continued: What]

1) Begin by showing students the four pictures of oceanographers in each main area of study, then ask them if they can identify what the four areas are.

   a. Example guiding question: *"There are four different areas of oceanography represented by these four pictures. Can anyone guess what areas these pictures may be representing?"*

2) As each area is identified, ask students what they think oceanographers in each of the areas do.

   a. *"Yes, this is a biological oceanographer, which means they study plants and animals in the ocean. What kind of things do you think they would be interested in researching?"*

3) As each area of study is identified, provide further explanation into what these oceanographers do and the types of collection methods they might use.

   a. *"They are interested in the numbers of marine organisms, their distributions, and how these organisms develop, relate to one another, adapt to their environment, and interact with it. To accomplish their work, they may use field observations, computer models, or laboratory and field experiments."*

4) Make sure to explain to students that these fields often overlap, and that data from one area can often inform or relate to another area.

5) Make sure all four areas have been identified, and that the associated interests and potential research methods have been discussed before moving on to the next slide.

[Slide 5: What (Video Examples)]

1) To highlight how oceanographers in the same field vary widely in their work, show students two "day in the life" videos of biological oceanographers.

   a. When Your Job Is Saving the Ocean | How She Works: https://www.youtube.com/watch?v=B-_dv0B0g1c (4:03 total)

    b. Day at Work: Ichthyologist (Fish Biologist): https://www.youtube.com/watch?v=51y_Ahx3Mxw (3:37 total)

2) Ask students to identify the differences between the two biological oceanographers work.
    a. Example of differences: one works with live animals and one works with dead animals, one works in the field and one works in a lab, etc.

[Slide 6: When]

When did oceanography become a scientific discipline?

1) To begin, ask students when they think oceanography officially became a scientific discipline. What do they think the first oceanographers did?
2) Explain to students that oceanography (while not explicitly called oceanography), began with explorers and merchants. The first true oceanographic expedition occurred on the HMS Challenger (left picture on slide) and sparked the eventual designation of oceanography as a scientific discipline.
3) Explain to students that ocean exploration and research is much more advanced these days, with research ships being superior in everything from plumbing and sleeping quarters, to food and research instruments.

[Slide 7: Where (Geographically + Focus on Oregon)]

1) Explain that oceanographic research happens all over the world, from blue whale research in New Zealand to studying how the ocean is changing on the Oregon Coast.


Where does oceanographic research happen?

→Oceanographic research happens all over the world

→Oregon is a VERY unique place for marine science, and attracts all types of oceanographers to come and study here!

2) Now bring the focus to Oregon, explaining that it is a very popular place for all types of oceanography due to unique phenomena and programs which heavily support research (like at OSU). Researchers from all over the world come to Oregon to study its coastal and marine environments.
    a. For physical oceanographers, there is the physical process of upwelling. Example explanation of upwelling – "*Imagine using your hands to spread apart the water in a pool or bathtub, what happens? Water from the bottom rushes in. This is essentially what's happening here, but wind is what separates the water from the shore. When the water from the deep comes up it is cold and full of nutrients, which means there is a lot of biological activity due to all of the available nutrients."*
    b. For biological oceanographers, there is the explosion of activity that results from upwelling, unique animals adapted to live in our sometimes-harsh climate, and animals that migrate through our waters each year such as Humpback and Gray whales.
    c. For chemical oceanographers, there are unique processes to observe like ocean acidification. Example explanation – *"Chemical oceanographers have access to studying the effects of what is called 'ocean acidification.' This is when increased carbon dioxide interacts with water producing a weak acid that lowers the pH of seawater that can lead to other changes in ocean chemistry."*
    d. For geological oceanographers, we live in a very exciting location with a lot of tectonic activity. Example – *"Oregon is located on the 'Cascadia subduction*

zone', where two of Earth's plates are slowly 'subducting' beneath the sea. This means that the Juan de Fuca plate is slowly being forced underneath the North American Plate, which creates all kinds of geological formations and can cause earthquakes. These earthquakes are actually being generated often, but are generally too small for us to feel."

[Slide 8: Where (Depth)]

1) Research also takes place at different *depths* of the ocean, not just different geographic locations.
2) Explain to students the different zones of the ocean, and how research efforts have varied by zone.

Where does oceanographic research happen?

- ➔Most research has historically taken place in the Epipelagic and Mesopelagic zones, which are considered "shallower" water.
- ➔In more recent times, more efforts have been dedicated to exploring the deeper, darker parts of the ocean.

   a. Example Guiding Question: *"What do you notice about the different zones of the ocean shown in this figure?"*
   b. Answers may include: different types of organisms present and different levels of light in each zone.

[Slide 9: Why]

1) Ask students to identify some reasons we would want to conduct marine science research and use marine science data.
   a. Curiosity – *"We still know more about the surface of the moon then we know about the oceans."*

Why do we conduct marine research and collect data?

- The ocean provides us with food, oxygen, affects our weather and climate, etc. It is important for our survival!
- The more we know about marine issues, the better we can solve them.

   b. The oceans are key to our survival – "*The oceans are important to your survival in many ways, including that they produce an estimated 45% of the oxygen we breath, provide billions of us with food, help regulate our weather and climate and could even provide us with new medicines."*

   c. Knowing more about an issue can help us solve the issue – *"The ocean is currently faced with some very important issues. Many of them being anthropogenic, which means caused directly by humans."*

2) Ask students to identify some human-caused impacts to the ocean, and explain how research and data could be used to address these problems. Examples shown on this slide in the PowerPoint include;

   a. Plastic pollution – *"Measuring how much plastic is in the ocean, how many animals ingest the plastic or are harmed by it, and identifying where plastic is coming from can help us to control the production, use and flow of it."*

   b. Coral die off – *"When water gets warmer, the symbiotic organisms that live within coral and provide it with food leave, which means the coral will turn white and die. Data that shows how the water is changing, how fast it's changing and why it's changing can help us take steps to keep coral healthy. Coral are the foundation of the coral reef ecosystem so it's important to preserve them or numerous other organisms that depend on them for survival risk perishing too."*

   c. Ships – *"Sometimes, ships can be troublesome for animals like whales. Large ships carrying cargo or people (like a cruise ship) can create a lot of noise, which can be disorienting to whales. Ships can also affect animals who are hunting or migrating as many use sound for locating prey and navigating. Research and data help us identify potential impacts, explore ways we can produce less noise, and help us determine alternate shipping routes to avoid striking animals."*

Wrap up:

1) If time allows, show students the following video from the College of Earth, Ocean and Atmospheric Science at Oregon State University to summarize everything covered in this lecture.
    a. https://youtu.be/LrCCM6cAPZ4 (5:24 total)
2) 1-Minute Papers Technique:
    a. Have students each fill out the 1-minute paper template (see Appendix). These can be turned in to teachers for review OR alternatively shared aloud with the class.

Assessment:

1) Did students actively participate in brain-storming and discussion?

2) Did student reflections in the 1-minute papers indicating understanding of the following key concepts:
    a. Data are important in our daily lives
    b. The ability to understand data are is important for a variety of reasons
    c. The who, what, when, where and why of oceanography

A SEA OF DATA: Lesson 2

Timeframe: 4 fifty-minute periods

Target Audience: 9th-12th Grade

Lesson Materials:

- A Sea of Data PowerPoint
- A Sea of Data graph handouts
- A Sea of Data instruction handouts
- A Sea of Data background handouts
- A Sea of Data map handouts
- A Sea of Data data-sheets
- Colored Pencils
- Rulers
- Poster materials

Objectives

Students will:

- Get a better understanding of three types of marine science data collection (CTD, Plankton Tow and Marine Mammal Surveys)
- Work collaboratively as their own "science party"
- Practice analyzing and interpreting data

Essential Questions

- What are some research techniques that oceanographers use?
- How can data tell a story?

Setup:

- Open PowerPoint

- Preload videos if preferred
- Prearrange students into groups of 3 or 4
- Assign one of the data activities to each group (CTD, Plankton Tow, Marine Mammals)
- For the CTD Groups: print out 1-2 background sheets, 1-2 sets of instructions, 1 map, 1 set of data, and four blank graphs
- For the Plankton Tow Groups: print out 1-2 background sheets, 1-2 sets of instructions, 1 map, 1 set of data and four blank graphs
- For the Marine Mammal Groups: print out 1-2 background sheets, 1 set of instructions, 1 map, 1 graph and 1 set of data

Teacher Background Information:

Important Terms

- CTD: an instrument that measures conductivity, temperature and depth in the water column. When graphing results from a CTD, “pressure” is used to represent “depth,” since pressure increases as depth increases.
- Conductivity: one way to measure the salinity of ocean water.
- Plankton Tow: a mesh net specifically designed for collecting plankton, that is dragged through the water either vertically or horizontally. As water flows out, planktonic organisms are concentrated in the cod end.
- Biomass: When graphing results from a plankton tow, biomass is often measured as “finalcarbon.”
- Plankton: Organisms that float in or drift with the currents in a body of water. Most plankton are very small, but many are not. Plankton are broken up into two distinct groups: phytoplankton, which photosynthesize, and zooplankton, who feed on phytoplankton and/or other zooplankton. Plankton make up the base of most ocean food chains.
- Sight Survey: a method used to observe marine mammals (species, numbers, behavior, etc.).

- Newport Line: a series of seven sampling stations that covers 25 miles perpendicular to the Oregon Coast.

The Activity Setting: R/V Oceanus Research Cruise

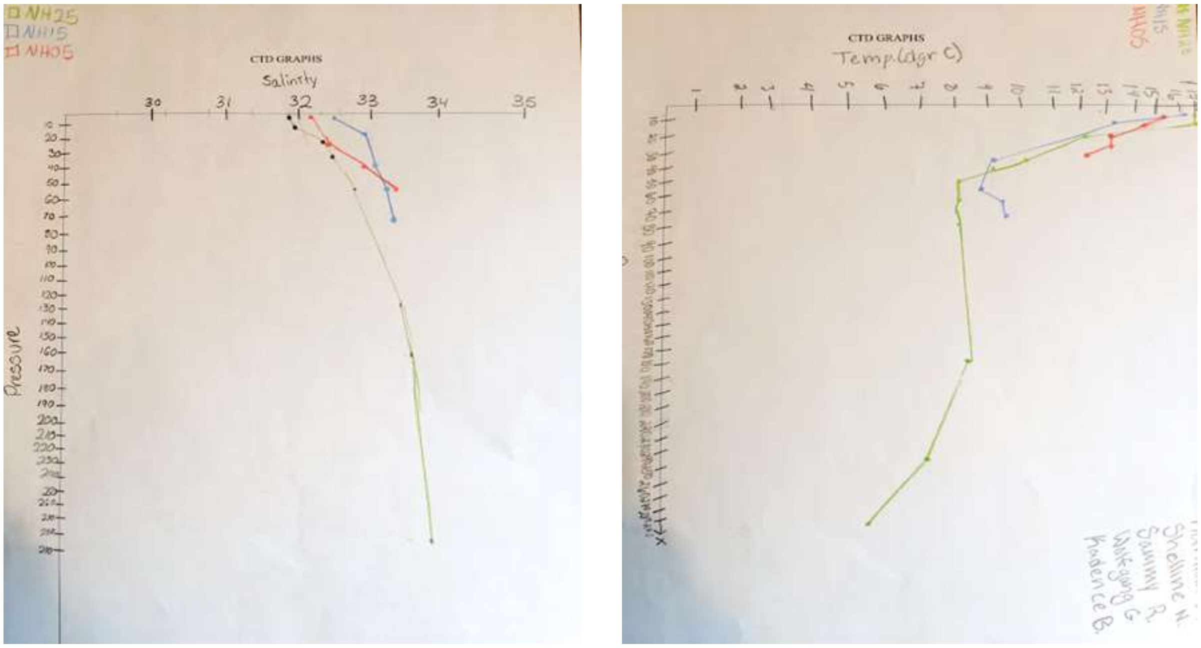
In this activity, students will act as “science parties” aboard the *R/V Oceanus* (which will be retired in 2020 and replaced with the *R/V Taani)*. The CTD and plankton tow data in this activity were collected on an *Oceanus* cruise from September of 2014. Marine mammal data from the 2014 cruise was unavailable, so marine mammal survey data from a National Marine Fisheries Service cruise is used in its place. This data was collected in the same general location, at a similar time, and utilized similar survey methods to an *Oceanus* cruise. Pictures and videos of research efforts in this lesson are from a 2018 cruise aboard the *Oceanus*, which involved full days of sight surveys, with CTD and Plankton Tow activities happening periodically each day as well.

The Research Tasks

Students will form “science parties” with a chief scientist and conduct data analysis of data collected from three stations along the Newport Line. They will then communicate the results to their peers.

For the CTD science parties: after reading their instructions and background information, those science parties assigned the CTD data will observe their map showing the three collection stations and take note of any interesting features. This should include the large canyon visible on the left side of the map and the distance of each of the sampling station from shore. Once oriented with the map, students will begin their data analysis. They will start by graphing the temperature vs pressure data, then salinity vs pressure data (pressure is often used as representative of depth, since pressure increases with depth). Once the graphs are complete, students will answer their discussion questions and identify any correlations and/or trends between salinity, temperature and depth, in relation to their map. If finished early, students should create a third graph of pressure (depth) vs oxygen and analyze it in the same fashion.

Once finished, students will prepare to share their results with their peers via a poster presentation.



Examples of pressure vs temperature and pressure vs salinity graphs

For the Plankton Tow science parties: after reading their instructions and background information, the science parties assigned plankton tow data will observe the map of the three collection stations and take note of any interesting features. This should include the large canyon visible on the left side of the map and the distance of each of the sampling stations from shore. Once oriented with the map, they will begin their data analysis. These students will construct three graphs, one for each sampling station. Make sure they pay close attention to the Site ID column in the data sheet. For each site, students will identify 3-5 of the species with the largest measurement of biomass (labelled as *finalcarbon)*, and construct bar graphs with *finalcarbon* on the y-axis and species on the x-axis. If finished early, students can construct a fourth graph showing overlap of species found at the three sampling stations. This final graph should have biomass on the y-axis and species on the x-axis with three different colored bars representing species found at each site. Students will answer discussion questions then prepare to share results and conclusions with their peers via a poster presentation.For the Marine Mammal Survey science party: after reading their instructions and background information, each science party assigned marine mammal survey data will observe the map of the three sampling stations and take note of any interesting features. This would include the large canyon visible on the left side of the map and the distance of each of the sampling stations from shore. Once oriented with the map, students will begin their data analysis. Students should start by mapping each species using latitude and longitude coordinates. Students will then construct a bar graph of species abundance for the data-set. Once these tasks are completed, students will answer discussion questions and prepare to share their results and conclusions with their peers via a poster presentation.

Activity:

[Slide 10]

Overview of the day

- Review data collection methods
- Form activity groups (3-4 people per group)
    - CTD groups
    - Plankton Tow groups
    - Marine Mammal groups
- Good science is all about collaboration and communication!

1) Begin class with an overview of the day, then review concepts from the previous day.
    a. Include a discussion about what data are and why data is important.
    b. Have students recall the 4 main fields of oceanography.
    c. Have students recall why we conduct oceanographic research.
    d. Explain that the activity will have them acting as scientists on one of OSU’s research vessels, the *R/V Oceanus*. They will be using real data collected off the coast of Oregon and will have to work together to analyze the data and share results with the rest of their “science party.”

[Slide 11]

Activity Setting: Oceanus Cruise

- A crew of different kinds of scientists
  - Water Chemistry
  - Plankton
  - Marine Mammals
- Different forms of data collection
  - CTD
  - Plankton Tow
  - Marine Mammal Surveys

1) Explain the activity setting to students: their science parties have just completed a multi-day cruise on the OSU Research Vessel the *R/V Oceanus*.
   a. Show students actual photos and video from a research cruise taken on the *Oceanus* (pictures and footage from the September 2018 cruise).
2) The cruise had multiple types of scientists on board, studying a variety of things including oceanographic data (collected using the CTD and flow through sensors), plankton and marine mammals.
   a. Guiding Question – *"What fields of oceanography are these topics representing?"*

[Slide 12]

Marine Mammal Surveys

Plankton Tow

CTD

1) Three different data collection techniques were used on the cruise.
2) A CTD – to measure conductivity (which is used to calculate salinity), temperature and depth (which is calculated from pressure readings).
3) A Plankton Tow – to collect samples of plankton at different locations and depths.
4) Marine Mammal Surveys – using binoculars and drones to observe location of marine mammals, number of individuals, species and behavior.

[Slide 13]

CTD Launch and Data Collection

1) Begin by showing students the embedded video of a CTD being deployed off of the side of the *R/V Oceanus* for data collection.
2) Explain to students that the two plots represent data collected on a single CTD deployment.
    a. Example Guiding Question – "*For the first graph, we have temperature along the top of the graph, or the x-axis. On the left side, or the y-axis, we have depth (which is represented by "pressure.") What do you notice about how the temperature changes with depth?"*
    b. Example Guiding Question – "*For the second graph, we have depth on the y-axis and salinity on the x-axis. What do you notice about how salinity changes with depth?"*

[Slide 14]

Plankton Tow

- A cone shaped net made of fine mesh
- Can be towed throughout the water column
- Gathers small fish and other animals
    - Who eats this stuff?

1) Begin by explaining to students what "plankton" actually are.
    a. Example – *"Plankton are organisms that live in water, and have little to no control over how the currents move them. They include organisms that will stay small, as well as baby organisms which will grow to be larger, like jellyfish, siphonophores, or squid."*
    b. If time, show students the following TEDTalk, "The Secret Life of Plankton." https://youtu.be/xFQ_fO2D7f0 (6:02 length)
2) Show the students pictures of what a nighttime plankton tow deployment looks like, as well as two examples of plankton.

3) Explain to students the process of a plankton tow.

    a. Example – "*A tow can be conducted either vertically in the water column while the vessel is stationary, or horizontally as the vessel moves. They can be done at a variety of depths for any length of time. The plankton are trapped in the net, and then collect at the bottom of a cannister. Samples are taken from the cannister and then analyzed in a lab. Samples are sorted for species and abundance. "Biomass" can be recorded to determine how many plankton there were per volume samples then extrapolated to provide an estimate for a larger area. This is done by weighing a sample, drying it at extreme heat to remove the water, then weighing it again."*

[Slide 15]

1) Explain to students what a marine mammal survey is.

Marine Mammal Surveys

- Observing ocean through the naked eye and binoculars.
- On this trip: the spatial ecologist also used drones!
- Record details about the marine mammal
    - Species/Age/Male or Female
    - Number of Animals
    - Their behavior: eating, travelling, etc.

    a. Example – *"marine mammal sight surveys, it is often a lot of standing around on the viewing platform waiting to spot something. Once a marine mammal is spotted, the researcher gives directions to the captain (approximate direction and distance) and the vessel is moved into a position for optimal observation using binoculars, a camera, or even a drone. While actively surveying researchers are "on effort." Often, marine mammal researchers will collect information along a transect, which is a designated path that can repeatedly followed over time to collect information. These transects are often used to collect "absence" and "presence" data which records whether an animal is present at a location or not. Researchers also record the number of species, their behavior, and if they are male or female (only possible for some species). When this information is compiled, it can tell researchers a lot about the* *relationship between where whales are and when. By adding in observations about behavior, researchers can often determine how these animals are utilizing these areas (for feeding, breeding, migrating, etc.).”*

[Slide 16]

1) If time, show students the following videos captured during OSU marine mammal surveys.
    a. Gray Whale off the Oregon Coast: https://www.youtube.com/watch?v=pNu7dv1Rp78
    b. Blue Whale Feeding in New Zealand: https://www.youtube.com/watch?v=cbxSBDopVyw

[Slide 17]

Activity Time

1) Set the scene by explaining to students they are acting like oceanographers who have just “finished” another Oceanus research cruise collecting similar data. Their individual science parties are each going to be looking at a different set (of real) data collected at sampling stations along the “Newport Line.”
2) Organize students into science parties for the activity (CTD, Plankton Tow and Mammal Surveys) and have them collect the required materials for their groups. Once everyone is settled, assign one person as the “Chief Scientist.”
3) The Chief Scientist will help assign jobs to the other members of their party (for example, the Chief Scientist can read directions, one person can scan data, one person can graph, one person can record results, etc.) The science party will need to work together to make sure things run smoothly and all tasks are completed on time.

4) Begin by having each party read their research activity instructions and confirm they understand their assigned tasks.
5) Allow students to work through their tasks, answering questions as needed, and making sure students are on the right track with their discussion questions (see Appendix for teacher answer keys).

[Slide 18]

1) Explain to students that communicating data and findings are an important part of science, and that they will practice this by creating a brief poster presentation demonstrating their data set, assigned tasks, what they found (results) and why they think it is important (conclusions).

Presentations

- What data set did your group have?
- What did you do with your data?
- What important things did you find?
- Why do you think this data could be important?

2) Have each science party create an informative poster that explains:
    a. What data collection technique they had, what data was collected and how.
    b. What their task was.
    c. What their results were.
    d. Findings from the discussion questions (any patterns or trends, any anomalies, and why they think they are important).
3) Allow students in class time to brainstorm and create posters.

[*Slide 18 continued]*

1) Have science parties present their posters. Allow students to ask questions once each presentation is over and have presenters respond to the best of their abilities.

2) Here, students should connect the pieces of the “jigsaw” to understand that the three data sets collected tell a story when put together. Water quality properties can impact where and how much plankton there are, which can in turn impact how many marine mammals (that feed on plankton) there are in an area. The combination of data sets can tell us a story about how the ecosystem is working, and what would potentially happen to it if circumstances changed.

Optional Lesson Three – near real-time data extension:

1) This lesson will take two, 50-minute class periods.
2) “Well, well, well” – a lesson developed by NANOOS, which allows students to not only explore an oceanographic data portal, but connect what they have learned about water quality, plankton levels, and upwelling on the Oregon Coast while utilizing near real-time data. This lesson requires access to a computer lab or Google Chromebooks, and includes a lab demonstration of upwelling. This lesson should be conducted after the poster presentations are completed, but before the final discussion.

- Source: http://www.nanoos.org/education/pdfs/well_well_well.pdf

A SEA OF DATA: Lesson 4

Timeframe: One 50-minute period

Target Audience: 9th-12th Grade

Suggested Materials:

- A Sea of Data PowerPoint

Lesson Objectives

Student's Will:

- Reflect on and discuss what they have learned about oceanography
- Reflect on and discuss what they have learned about data
- Reflect on and discuss why the field of oceanography and data are important
- Reflect on and discuss why this field and data are relevant to them

Essential Questions

- Why is science research important?
- Why is it important to be able to find and understand data?
- What can data help us accomplish?
- How is marine science research and data relevant to us?

Setup

- Open PowerPoint

Activity

[*Slide 19]*

1) Once presentations and/or “well, well, well” are complete, gather students for a final discussion about the key topics in the lessons; oceanography, research and data.
2) The following questions can be included in the discussions:
    a. What did you learn about marine science research?
    b. Why is it important?
    c. What did you learn about marine science data?
    d. Do you feel like you have a better understanding of research and data?
    e. Why is it important to be able to find and understand data?
    f. What kind of things can data help us do?
    g. How do you think this information relates to your life?

Discussion

- What did you learn about marine science research?
- What did you learn about marine science data?
- Why is it important to have marine science research?
- Do you feel like you have a better understanding of research and data?
- Why is it important to be able to find and understand data?
    - What kind of things can data help us do?
- How do you think this information relates to you?

Assessment:

1) Did students participate in class discussion and demonstrate an understanding of the basics of oceanography?
2) Did students accurately interpret and demonstrate an understanding of different types of data collection methods and the data they produce?
3) Did students accurately graph and interpret their individual data sets?
    a. For example, the CTD students should show understanding that there is a relationship between salinity, depth/pressure, and temperature.
4) Did students actively participate in group presentations?
5) Did students actively participate in the final class discussion and demonstrate an understanding of oceanography, marine research and the importance of data.

Additional Resources:

The RCRV Project at Oregon State University is committed to assisting teachers in pursuing data-focused learning in their classrooms. Please visit the RCRV website for general information about the project, ship design and capabilities, timelines and frequently asked questions. The RCRV outreach page is being continuously updated with new information about professional development opportunities, lesson plans, contacts and other helpful resources. As the project progresses and the R/V Taani goes live (projected for 2022), some lesson plans will integrate real-time data collected from the vessel.

- Regional Class Research Vessel (RCRV) Homepage:
  https://ceoas.oregonstate.edu/ships/rcrv/
- RCRV Education & Outreach Page:
  https://ceoas.oregonstate.edu/ships/rcrv/outreach/

Additionally, there are a variety of other programs that also provide data-focused learning activities and resources for teachers that may be helpful.

- The Monterey Bay Aquarium Research Institute (MBARI) Education And Research: Testing Hypotheses (EARTH) Program:
  https://www.mbari.org/products/educational-resources/earth/
- The Consortium for Ocean Science Exploration and Engagement (COSEE)
  http://www.cosee.net/resources/educators/
- Oceans of Data Institute (ODI):
  http://oceansofdata.org/
- The National Oceanic and Atmospheric Administration (NOAA) Data in the Classroom:
  https://dataintheclassroom.noaa.gov/
- The National Estuarine Research Reserve System (NERRS)
  https://coast.noaa.gov/nerrs/education/

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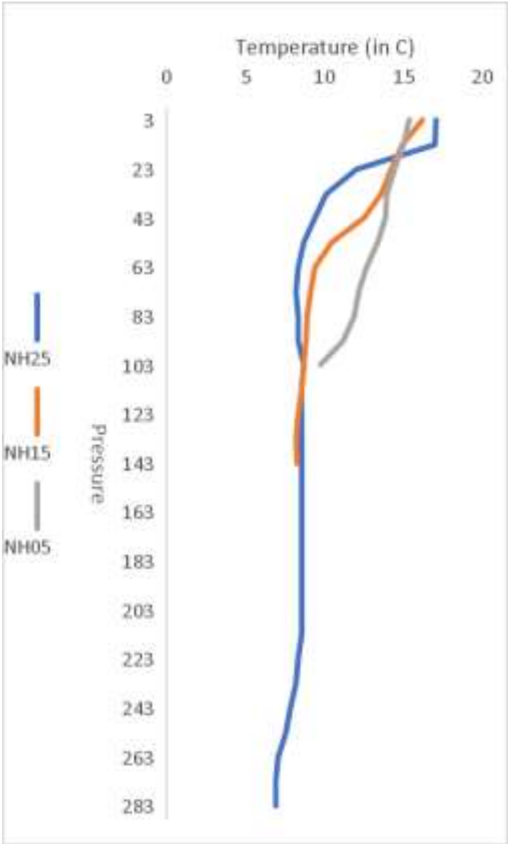
Appendix B: Teacher Materials

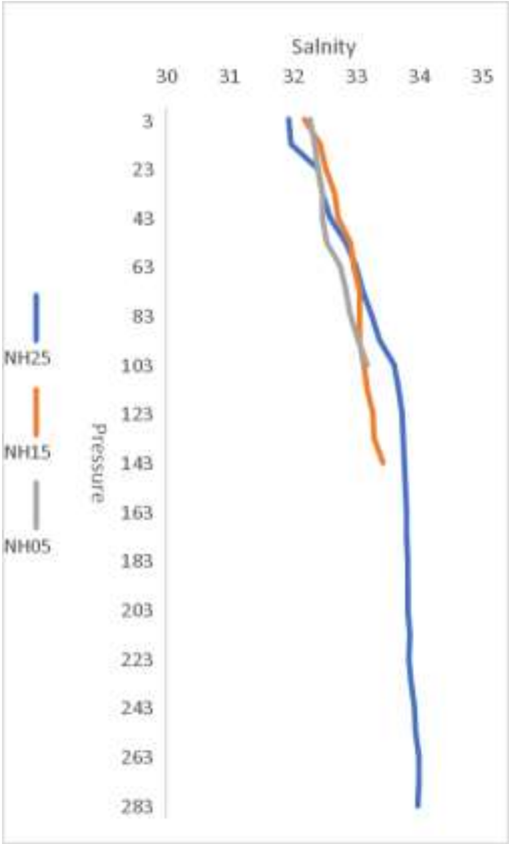
CTD SCIENCE PARTY INSTRUCTIONS (Teacher Guide)

Make sure your science party has copies of the CTD background sheet, the CTD data set, a map, two blank graph sheets and three different colored pens or pencils.

1) Read your background sheet.
2) Your science party will be looking at a set of real CTD (conductivity, temperature and depth) data. The oceanographic data are all from the same day but were collected at three different sampling stations along the Newport line. The three stations we are working with are represented by "NH05," "NH15," and "NH25." Take a look at your map of CTD stations.
    a. What do you notice about the three different sites?
        i. They are equally spaced apart.
    b. How do you think the ocean conditions (depth, wind, etc.) might vary at each site? Do you notice anything about the seafloor? Once you've come up with some ideas, share with your teacher to see if you're on the right track.
        i. There is a large canyon to the left of the map.
        ii. The depth increases as you get further from shore.
3) Now take a look at your data sheet, be sure to ask for help if you are confused about it.
4) Next, locate your graph sheets. You are going to make one graph for salinity (x-axis) vs pressure (y-axis), and a second graph for temperature (x-axis) and pressure (y-axis).
    a. You should have three different colored lines on each graph, one for each station.

b. **Remember that you can utilize "pressure" as a representation for depth. See example graphs below:**





5) Once you have completed your graphs, double check you are on the right track.

   a. What kind of patterns do you notice?

      i. Salinity increases with pressure/depth, temperature decreases with pressure/depth.

   b. Do any of the measurements differ between stations? If yes, which ones? Can you come up with an explanation or a hypothesis for why they might be different?

      i. Example: depth increases with NH Station as you get further from shore.

   c. Why do you think it is important that real, current data is available for things like temperature and salinity off of our coast? Who could benefit from that information?

      i. Examples include: it can help identify how ocean conditions are changing, it can help identify environmental preferences for species, it can help fishermen find the right area for target species, etc.

6) If you complete your graphs and discussion early, create a third graph looking at pressure vs. oxygen concentration, then complete the discussion questions.

7) Be prepared to give a brief overview to your classmates about what your science party did and found with the data. You should be prepared to talk about:

   i. What your data set was
   ii. What your analysis task was
   iii. What the results were
   iv. Any hypotheses you might have or additional questions
   v. Why you think it's important

PLANKTON TOW SCIENCE PARTY INSTRUCTIONS (Teacher Guide)

Make sure your group has copies of the plankton background sheet, plankton tow (PT) data sheet, a PT map, 3-4 blank graph sheets and different colored pens or pencils.

1) Read your background sheet.

2) Your science party will be looking at a set of real plankton tow data. The data are from the same day but three different sampling stations along the Newport line. The three stations we are working with are represented by "NH05," "NH15," and "NH25." Take a look at your map of plankton tow stations.

    a. What do you notice about the three different sites?

        i. They are equally spaced apart.

        ii. NH 05 is close to shore while NH25 is the furthest out.

        iii. The seafloor around NH25 looks different than NH05 and NH15.

    b. How do you think the ocean conditions (depth, wind, etc.) varies at each site? Do you notice anything about the seafloor? Once you've come up with some ideas, share with your teacher to see if you're on the right track.

        i. There is a large canyon to the left of the map.

        ii. The depth increases as you get further from shore.

3) Now take a look at your data sheet, pay attention to the columns labeled "Station," "Genus Species" and "FinalCarbon**." Remember, the "FinalCarbon" column is how we measure biomass.** Be sure to ask for help if you are confused about anything. For each of the three stations, look at your data sheet and circle or highlight the 3-5 species that have the highest biomass or "FinalCarbon" measurements.

4) Now, using your graph sheets, make 3 bar graphs , one for each station showing the species and associated biomasses you identified in Step 3. On the x-axis, add the species names. On the y-axis, add the "Final Carbon measurements."

    See highest counts for each station and example graphs below –

    a. NH 5:

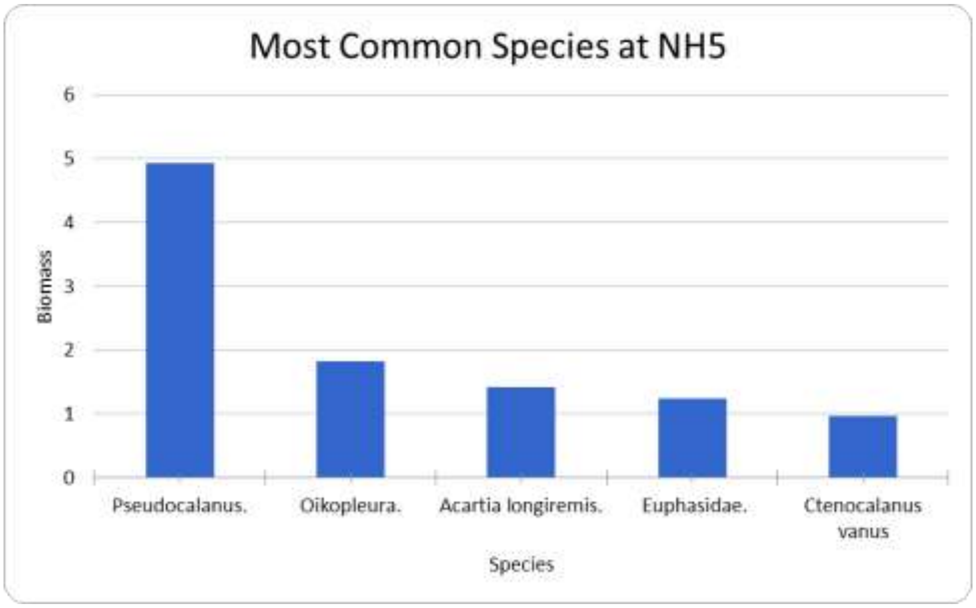
        i. Pseudocalanus.

        ii. Oikopleura.

iii. *Euphasidae.*

iv. *Acartia longiremis.*

v. *Ctenocalanus vanus.*



b. NH15:

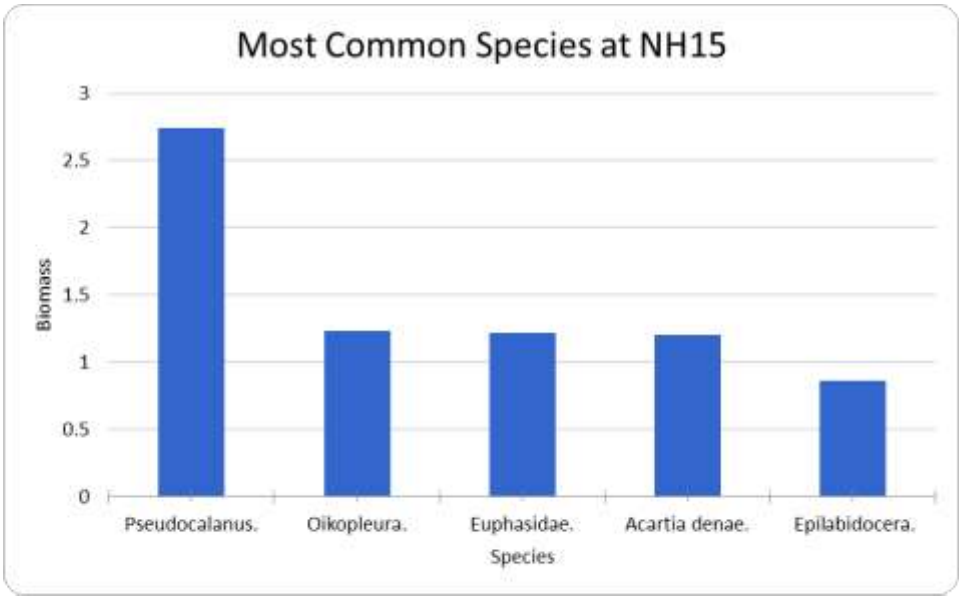
i. *Acartia denae.*

ii. *Euphasidae.*

iii. *Oikopleura.*

iv. *Pseudocalanus.*

   v. *Epilabidocera.*



c. NH25:

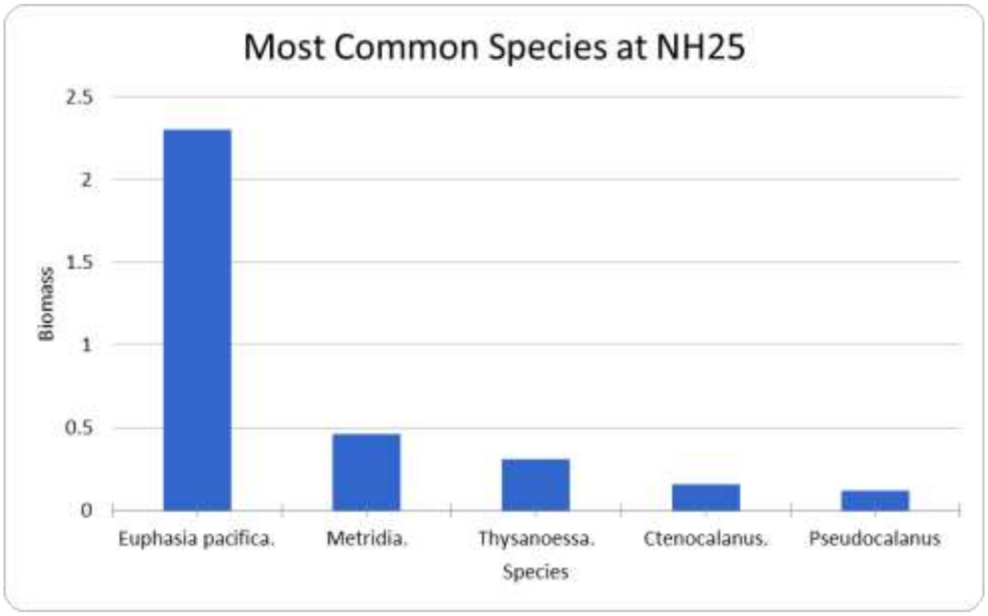
   i. *Euphasia pacifica.*

   ii. *Metridia.*

   iii. *Thysanoessa.*

   iv. *Ctenocalanus.*

v. *Pseudocalanus.*



5) Once you have completed your graphs, answer the following questions:

   a. What patterns do you notice? Do any of the measurements differ between stations? If yes, which ones?

      i. Examples include: Pseudocalanus appeared in all three stations and had a large biomass in the first two stations but not the last. Oikopleura appeared in the first two stations but not the last. Ctenocalanus appeared in the first and the last stations but not the second.

   b. Can you come up with an explanation for why these samples might be different?

      i. Examples include: different plankton are found in different environmental conditions and currents which may occur in different locations. Certain types of plankton are preferred by predators and may be removed through heavy feeding.

   c. Why do you think it's important we have real, recent data for things like plankton?

      i. Examples include: It can tell us about currents, productivity or the nutrient content in the water (if there are a lot of plankton in the water there are probably a lot of nutrients – **like from upwelling!**) and can help predict where predators may be found.

6) Be prepared to give a brief overview to your classmates about what your science party did and found with their data. You should be prepared to talk about the following:
    i. What your data set was.
    ii. What your analysis task was.
    iii. What the results were.
    iv. Discuss any hypotheses you have or any questions.
    v. Why you think it's important.

MARINE MAMMAL SCIENCE PARTY INSTRUCTIONS (Teacher Guide)

Make sure your science party has copies of the marine mammal background sheet, the marine mammal data sheet, a blank map and three different colored markers or pencils.

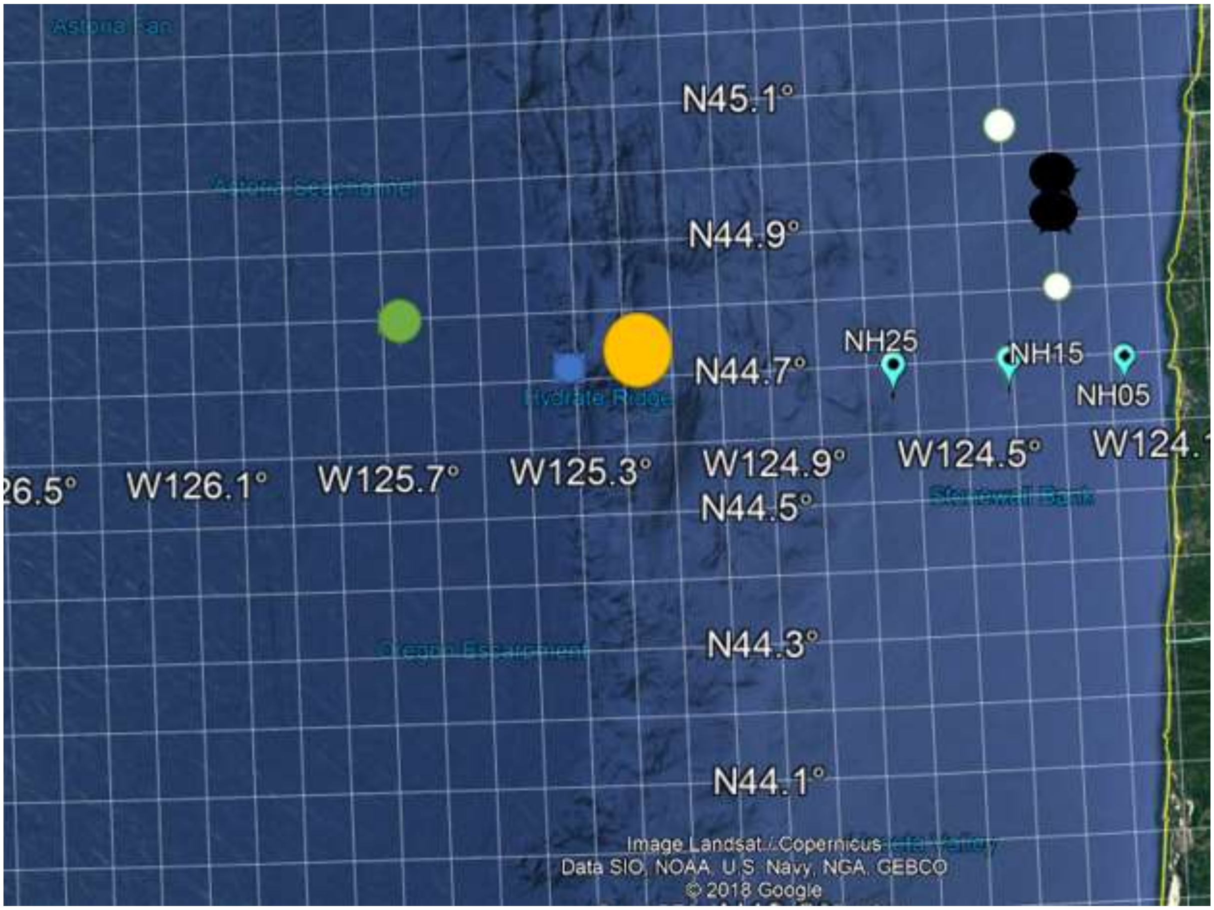
1) Read your background sheet, paying close attention to the most commonly found species of whales, dolphins and porpoises found in Oregon.

2) Your party will be looking at a set of marine mammal survey data. These data are real and collected from the Oregon Coast. Locate your map.
    a. On your map, you will see three points labeled "NH05," "NH15," and "NH25." These are stations along the Newport line where the CTD and Plankton Tow data were also collected.

3) Now, take a look at your data. This is a simplified view of marine mammal survey data. It has the species name, the latitude and longitude the animal was spotted at, and how many individuals were there.

4) On your map, locate the latitude and longitude lines. Begin to fill in the locations of where these animals were spotted. Decide on a system that shows what kind of animal it is, whether that's a color, shape, labelling it, etc.

a. Be sure to provide a key so others can interpret your completed map. See an example map below, where the different species and species counts are represented circles. Here, the different colors represent different species, and the different sizes represent different counts. Students could also used different shapes or labels to represent this as well.



5) Once you have finished your map, locate your blank graphing sheet. On the x-axis, list each of the species you identified on your map. On the y-axis, put numbers of individuals. Make a bar graph showing how many individuals of each species was recorded. See correct species counts and an example bar graph below:

a. Megaptera – 4 total.

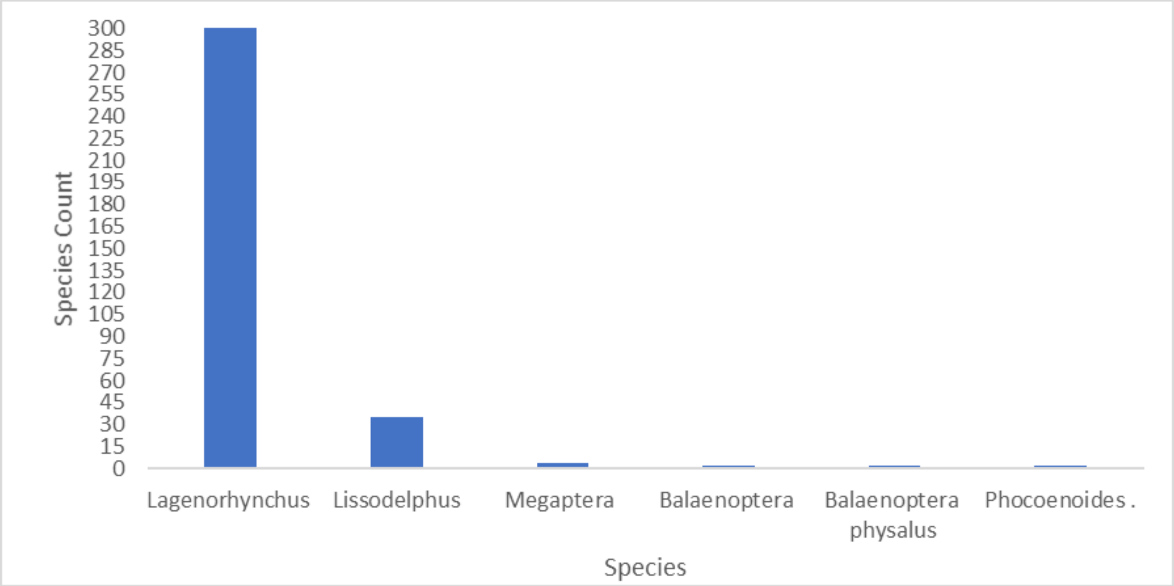
b. Lagenorhynchus – 315.

c. Lissodelphus – 35.

d. Balaenoptera – 2.

e. Balaenoptera physalus – 2.

f. Phocoenoides - 2.



6) Discuss the following questions with your party.

a. Does one species occur in a certain area more than another? If yes, why do you think that is?

   i. Megaptera, (the Humpback Whales) were seen closer to stations 5 and 15. A potential explanation could be a potential food source is found there. Phocoenoides, Lissodelphis and Lagenorhynchus were seen farther away from the stations. Potential explanations could include a different food source further away, avoidance of predators, preference for deeper water, etc.

b. Pay attention to the location of the stations where CTD and plankton tow data were collected. Are there any species that seemed to gather near one of the stations? Were there species that were seen farther out?

   i. The Balaenoptera were more dispersed among stations. Students may notice that some species were located near a canyon or other geological structures. This question is more about getting students to look for trends in numbers and think critically about why certain species could gravitate to a certain area.

c. Do you see a species in the surveys that is not listed on the species chart on your background sheet? If so, why do you think this species was seen off the coast?
    i. Yes – *Lissodelphus* is not included on the commonly seen list. This is the Right Whale Dolphin, and possible explanations for their presence could include: they are migrating, following a food source, avoiding predators, or their distribution has changed due to change in ocean conditions, etc.

d. What are some other measurements the science team could make, other than just presence/absence data?
    i. Possible suggestions include behavior (this is important, especially if they are feeding!) and relationship (a mom and calf for example).

e. Why do you think this "presence/absence" data is important?
    i. What could it be used for?
        1. Presence and absence can help tell us about preferred habitats, where preferred food sources are located, where predators may be/not be, etc. It can also inform marine spatial planning- which helps us decide where to allow/not allow fishing, place wave energy devices, develop marine protected areas, etc.

f. Be prepared to give a brief overview to your classmates about what your science party did and found with your data. You should be prepared to talk about:
    i. What your data set was
    ii. What your analysis task was
    iii. What the results are

iv. Discuss any hypotheses you have or any questions

v. Why you think it’s important to collect this type of data

Appendix C: Student Materials

THE 1-MINUTE PAPER

Please answer the three questions below to the best of your abilities:

1. What are the 3-5 most important things you have learned during this session?

2. What questions stand out in your mind?

3. Is there anything you did *not* understand?

CTD SCIENCE PARTY INSTRUCTIONS

Make sure your science party has copies of the CTD background sheet, the CTD data set, a map, 2-3 blank graph sheets and three different colored pens or pencils.

1) Read your background sheet.
2) Your party will be looking at a set of real CTD (conductivity, temperature and depth) data. The oceanographic data are all from the same day, but at three different sampling stations along the Newport line. The three stations we are working with are represented by “NH05,” “NH15,” and “NH25.” Take a look at your map of CTD stations.
   a. What do you notice about the three different sites?
   a. How do you think the ocean conditions (depth, wind, etc.) varies at each site? Do you notice anything about the seafloor? Once you’ve come up with some ideas, share with your teacher to see if you’re on the right track.
3) Now take a look at your data sheet, be sure to ask for help if you are confused about it.
4) Next, locate your graph sheets. You are going to make one graph for salinity (x-axis) vs pressure (y-axis), and a second graph for temperature (x-axis) and pressure (y-axis).
   a. You should have three different colored lines on each graph, one for each station.
   b. Remember that you can utilize “pressure” as a representation for depth here.
5) Once you have completed your graphs, double check you are on the right track.
   a. What kind of patterns do you notice first?
   b. Do any measurements differ between stations? If yes, which ones? Can you come up with an explanation or a hypothesis for why they might be different?
   c. Why do you think it’s important we have real, current data for things like temperature and salinity off of our coast? Who could benefit from that information?

6) If you complete your graphs and discussion early, create a third graph looking at pressure vs. oxygen concentration, and complete the discussion questions.

7) Be prepared to give a brief overview to your classmates about what your science party did and found with their data. You should talk about:

    i. What your data set was
    ii. What your analysis task was
    iii. What the results were
    iv. Any hypotheses you might have or additional questions
    v. Why you think it's important

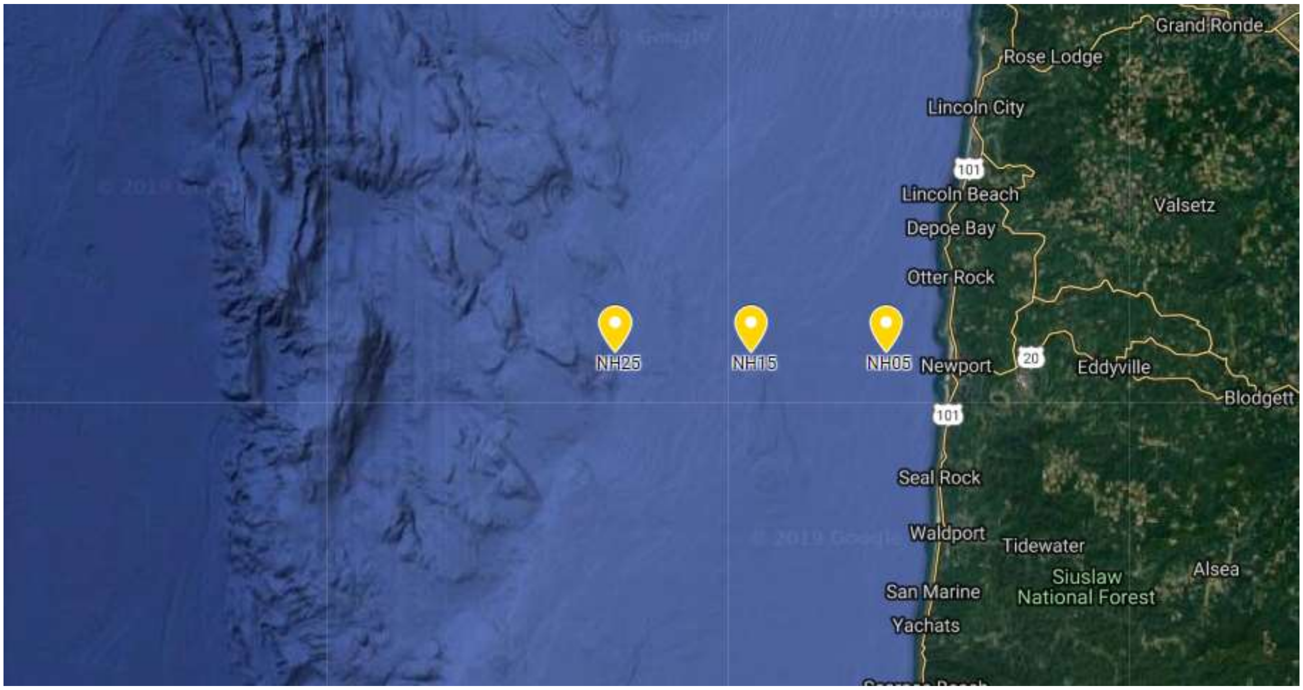
CTD SCIENCE PARTY BACKGROUND

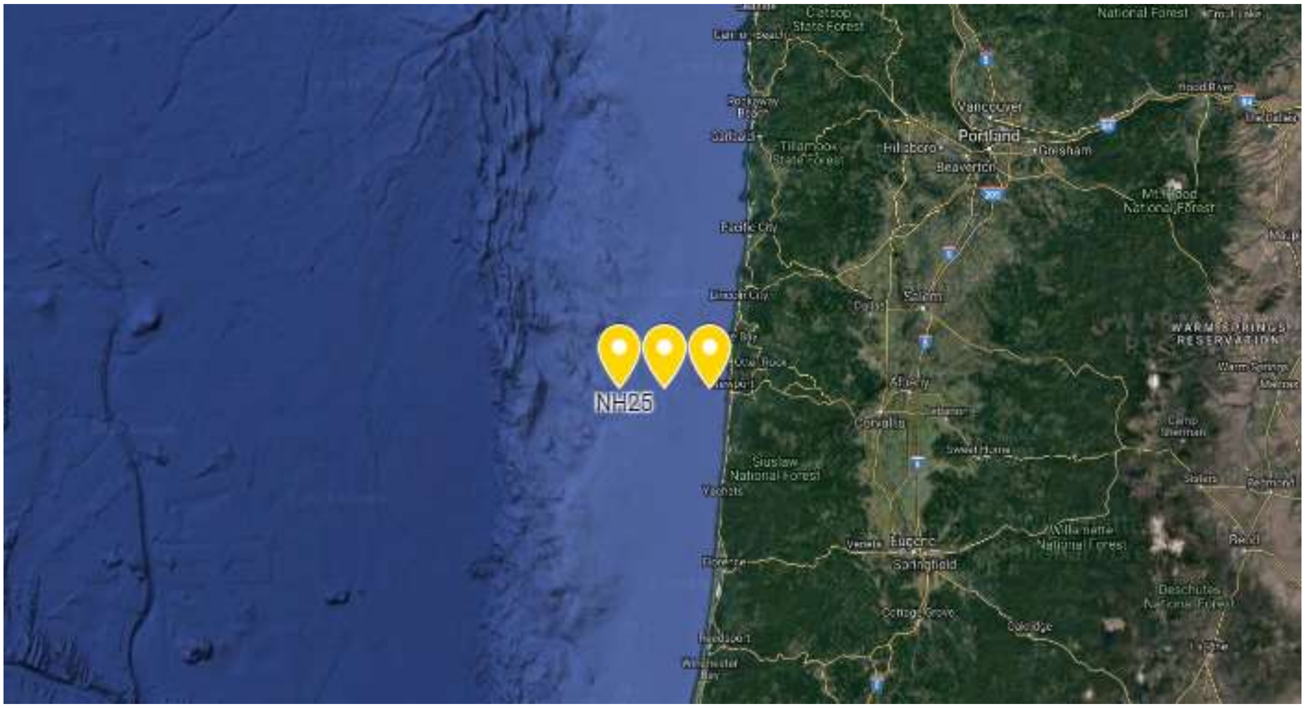
- What is a CTD?
    - A device that takes measurements through the water column. Measurements include *conductivity* and *temperature* in relation to *depth*.
        - Conductivity is a measurement of how well water conducts electricity, and is related to salinity.
        - Salinity is how "salty" the water is.
        - Temperature is how cool or warm the water is.
- **On many CTD graphs, depth is related by "Pressure."** This is because as you descend deeper into the water, the pressure will grow by 1 *atmosphere (atm)* every 10 meters depth.
    - An *atmosphere* is a measurement of pressure. 1 atmosphere = the amount of pressure gravity is exerting on you when you are sitting in class, or on an object on the surface of the water.
    - So, at 10 meters depth = 2 atmospheres. (1 atmosphere at the surface + 1 atm for the first 10 meters). 20 meters depth = 3 atmospheres, and so on.
- How do the bottles work?
    - Each bottle can be triggered to close at a variety of depths, to study changes throughout the water column.

Images from September 2018 R/V Oceanus Cruise

NEWPORT LINE STATION MAP

(The same map, one zoomed in and one zoomed out).





CTD GRAPHS

CTD GRAPHS

CTD SCIENCE PARTY DATA

CTD SITE LOCATION	Date	Pressure	Temperature (in C)	Salinity	Oxygen (ml/L)
093014NH25	30-Sep-14	3	17.1086	31.9439	5.31257
093014NH25	30-Sep-14	13	17.0061	31.9794	5.47155
093014NH25	30-Sep-14	23	12.0323	32.3964	6.3451
093014NH25	30-Sep-14	33	10.113	32.4707	5.95099
093014NH25	30-Sep-14	43	9.3967	32.5896	5.55405
093014NH25	30-Sep-14	53	8.7062	32.8352	5.0913
093014NH25	30-Sep-14	63	8.3669	33.0043	4.89443
093014NH25	30-Sep-14	73	8.1937	33.109	4.69139
093014NH25	30-Sep-14	83	8.3221	33.248	4.3644
093014NH25	30-Sep-14	93	8.3489	33.3845	4.00404
093014NH25	30-Sep-14	103	8.7246	33.6143	3.05248
093014NH25	30-Sep-14	113	8.5859	33.6789	2.6563
093014NH25	30-Sep-14	123	8.5825	33.7381	2.3777
093014NH25	30-Sep-14	133	8.582	33.7587	2.26832
093014NH25	30-Sep-14	143	8.58	33.7746	2.17581
093014NH25	30-Sep-14	153	8.5826	33.7899	2.06632
093014NH25	30-Sep-14	163	8.5632	33.8002	1.99046
093014NH25	30-Sep-14	173	8.5691	33.8072	1.9509
093014NH25	30-Sep-14	183	8.557	33.8128	1.93573
093014NH25	30-Sep-14	193	8.5536	33.8173	1.90262
093014NH25	30-Sep-14	203	8.5305	33.8227	1.88952
093014NH25	30-Sep-14	213	8.5893	33.8567	1.90546
093014NH25	30-Sep-14	223	8.3532	33.8441	1.87263
093014NH25	30-Sep-14	233	8.2033	33.8689	1.89057
093014NH25	30-Sep-14	243	7.8423	33.9245	1.91331
093014NH25	30-Sep-14	253	7.5376	33.9514	1.87617
093014NH25	30-Sep-14	263	7.0344	34.0012	1.76914

093014NH25	30-Sep-14	273	6.9243	33.9962	1.68933
093014NH25	30-Sep-14	283	6.9138	33.9902	1.68367
093014NH15	30-Sep-14	5	16.2707	32.1782	5.53941
093014NH15	30-Sep-14	10	14.984	32.4314	6.06095
093014NH15	30-Sep-14	15	14.2566	32.5239	6.28383
093014NH15	30-Sep-14	20	13.6366	32.6675	6.42766
093014NH15	30-Sep-14	25	12.5121	32.7162	5.92987
093014NH15	30-Sep-14	30	10.4528	32.9068	5.39595
093014NH15	30-Sep-14	35	9.3798	32.9734	4.87735
093014NH15	30-Sep-14	40	9.1578	33.0509	4.71132
093014NH15	30-Sep-14	45	8.9394	33.0592	4.61839
093014NH15	30-Sep-14	50	8.8757	33.0578	4.55618
093014NH15	30-Sep-14	55	8.6735	33.1219	4.37003
093014NH15	30-Sep-14	60	8.555	33.1818	4.29622
093014NH15	30-Sep-14	65	8.3538	33.2651	4.10412
093014NH15	30-Sep-14	70	8.2361	33.2901	4.12298
093014NH15	30-Sep-14	75	8.2912	33.4281	3.58782
093014NH05	30-Sep-14	5	15.414	32.2789	5.57483
093014NH05	30-Sep-14	10	15.054	32.3449	5.67728
093014NH05	30-Sep-14	15	14.4574	32.4064	5.64087
093014NH05	30-Sep-14	20	13.9518	32.4754	5.68947
093014NH05	30-Sep-14	25	13.8801	32.463	5.75205
093014NH05	30-Sep-14	30	13.3908	32.5478	5.70263
093014NH05	30-Sep-14	35	12.6497	32.7516	5.82816
093014NH05	30-Sep-14	40	12.1973	32.8526	5.80533
093014NH05	30-Sep-14	45	11.9274	32.9213	5.90807
093014NH05	30-Sep-14	50	11.1979	33.0446	5.49866
093014NH05	30-Sep-14	55	9.7402	33.1874	4.43337

Data was collected in Sept 2014 via the R/V Oceanus

PLANKTON TOW SCIENCE PARTY INSTRUCTIONS

Make sure your party has copies of the plankton background sheet, plankton tow (PT) data sheet, a PT map, 3-4 blank graph sheets and different colored pens or pencils.

1) Read your background sheet.
2) Your science party will be looking at a set of real plankton tow data. The data are from the same day, but three different sampling stations along the Newport line. The three stations we are working with are represented by “NH05,” “NH15,” and “NH25.” Take a look at your map of plankton tow stations.
    a. What do you notice about the three different sites?
    b. How do you think the ocean conditions (depth, wind, etc.) varies at each site? Do you notice anything about the seafloor? Once you’ve come up with some ideas, share with your teacher to see if you’re on the right track.
3) Now take a look at your data sheet, pay attention to the columns labeled “Station,” “Genus Species” and “FinalCarbon**.” Remember, the “FinalCarbon” column is how we measure biomass.** Be sure to ask for help if you are confused. For each of the three stations, look at your data sheet and identify 3-5 species that have the highest biomass or “FinalCarbon” measurements.
4) Now, using your graph sheets make 3 bar charts, one for each station showing the species and associated biomasses you identified in Step 3. On the x-axis add the species names. On the y-axis add the “Final Carbon measurements.”
5) Once you have completed your graphs, answer the following questions:
    a. What patterns do you notice? Do any of the measurements differ between stations? If yes, which ones?
    b. Can you come up with an explanation for why these samples might be different?

    c. Why do you think it's important we have real, recent data for things like plankton?

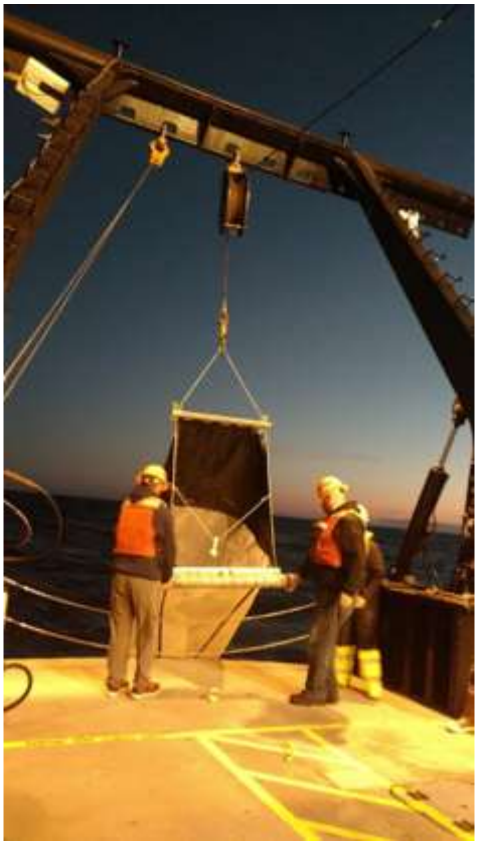
6) Be prepared to give a brief overview to your classmates about what your party did and found with their data. You should be prepared to talk about the following:

    i. What your data set was
    ii. What your analysis task was
    iii. What the results were
    iv. Discuss any hypotheses you have or any questions
    v. Why you think it's important

PLANKTON TOW SCIENCE PARTY BACKGROUND

- What are plankton?
    - The word *plankton* comes from the Greek word for "wanderer." Plankton are free-floating animals in the water column. There are phytoplankton, which

photosynthesize and produce oxygen, and zooplankton, which are predators of phytoplankton and other zooplankton.



- Why are plankton important?
    - They form the basis of the food chain, as well as provide oxygen and other nutrients.
- What is a plankton tow?
    - A plankton tow is the process of dropping a *plankton net* into the water column and towing it for a specific period of time. The plankton is trapped between the fine mesh of the net and transferred into a cannister (or “cod end”) at the end of the net.
- How is *biomass* measured?
    - Biomass is measured in your data by “FinalCarbon.” This is a measurement used by scientists that involves drying a sample at high temperatures andweighing what remains of the sample, then relating the mass to the volume of water that was sampled.
- Some examples of plankton commonly found off of the Oregon Coast

Oikopleura

Pseudocalanus

Euphausiid (krill)

Images:

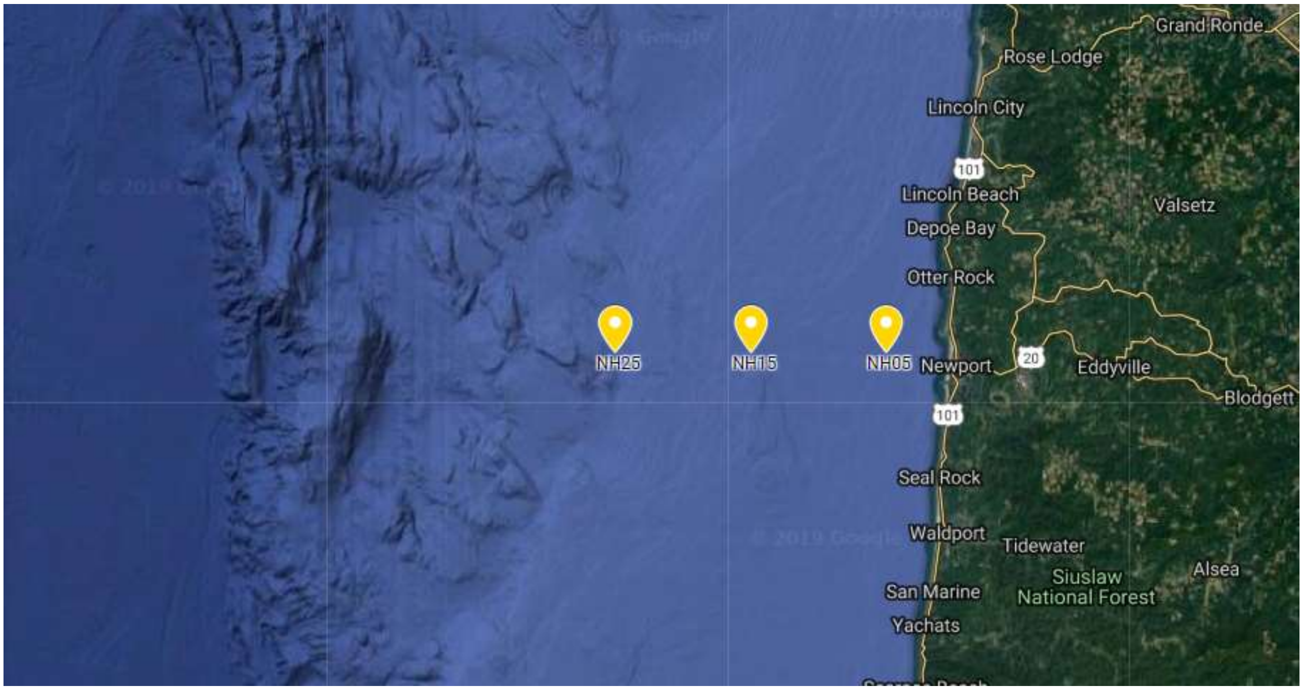
https://scripps.ucsd.edu/zooplanktonguide/species/oikopleura-dioica

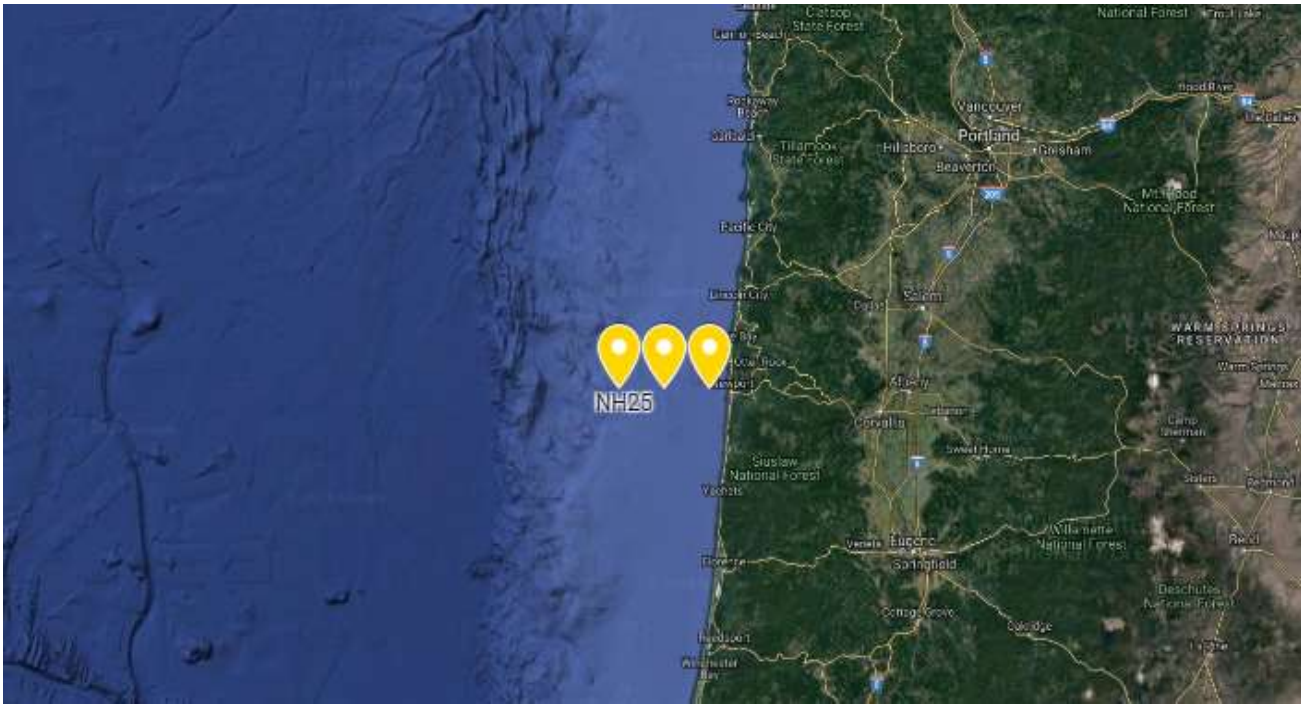
http://www.marinespecies.org/aphia.php?p=taxdetails&id=104165

https://en.wikipedia.org/wiki/Krill#/media/File:Meganyctiphanes_norvegica2.jpg

NEWPORT LINE SAMPLING STATION MAP

(The same map, one zoomed in and one zoomed out).





Plankton Tow Graph Sheet

PLANKTON TOW SCIENCE PARTY DATA

DATE	SITE	SPECIES	BIOMASS
30-Sep-14	NH05	ACARTIA DANAE	0.08241
30-Sep-14	NH05	ACARTIA LONGIREMIS	1.4184
30-Sep-14	NH05	BARNACLES	0.5237
30-Sep-14	NH05	CALANUS PACIFICUS	0.414149
30-Sep-14	NH05	CALOCALANUS STYLIREMIS	0.017081
30-Sep-14	NH05	CENTROPAGES ABDOMINALIS	0.02113
30-Sep-14	NH05	CHAETOGNATHA	0.034647
30-Sep-14	NH05	CLAUSOCALANUS	0.34906
30-Sep-14	NH05	CORYCAEUS ANGLICUS	0.01217
30-Sep-14	NH05	CTENOCALANUS VANUS	0.96763
30-Sep-14	NH05	DOLIOLETTA GEGENBAURI	0.50735
30-Sep-14	NH05	EUCALANUS	0.06122
30-Sep-14	NH05	EUPHAUSIA PACIFICA	0.1519
30-Sep-14	NH05	EUPHAUSIIDAE	1.24742
30-Sep-14	NH05	EVADNE	0.24006
30-Sep-14	NH05	FISH	0.0396
30-Sep-14	NH05	MESOCALANUS TENUICORNIS	0.0225
30-Sep-14	NH05	OIKOPLEURA	1.8379
30-Sep-14	NH05	OITHONA SIMILIS	0.63334
30-Sep-14	NH05	ONCAEA	0.00108
30-Sep-14	NH05	PARACALANUS PARVUS	0.23947
30-Sep-14	NH05	PODON	0.01691
30-Sep-14	NH05	PSEUDOCALANUS	4.943769
30-Sep-14	NH05	THYSANOESSA SPINIFERA	0.14722
30-Sep-14	NH05	TORTANUS DISCAUDATUS	0.10147

30-Sep-14	NH15	ACARTIA DANAE	1.2074
30-Sep-14	NH15	ACARTIA LONGIREMIS	0.584
30-Sep-14	NH15	BARNACLES	0.005
30-Sep-14	NH15	CALANUS MARSHALLAE	0.0021
30-Sep-14	NH15	CALANUS PACIFICUS	0.0678
30-Sep-14	NH15	CHAETOGNATHA	0.5402
30-Sep-14	NH15	CLAUSOCALANUS PERGENS	0.0584
30-Sep-14	NH15	CORYCAEUS ANGLICUS	0.0031
30-Sep-14	NH15	CTENOCALANUS VANUS	0.0317
30-Sep-14	NH15	DOLIOLETTA GEGENBAURI	0.1758
30-Sep-14	NH15	EPILABIDOCERA LONGIPEDATA	0.8691
30-Sep-14	NH15	EUPHAUSIIDAE	1.2293
30-Sep-14	NH15	EVADNE	0.1981
30-Sep-14	NH15	LIMACINA	0.0142
30-Sep-14	NH15	MESOCALANUS TENUICORNIS	0.1836
30-Sep-14	NH15	METRIDIA	0.0351
30-Sep-14	NH15	MUGGIAEA	0.2701
30-Sep-14	NH15	OIKOPLEURA	1.2737
30-Sep-14	NH15	OITHONA SIMILIS	0.4938
30-Sep-14	NH15	PARACALANUS PARVUS	0.4477
30-Sep-14	NH15	PODON	0.0351
30-Sep-14	NH15	PSEUDOCALANUS	2.7455
30-Sep-14	NH25	ACARTIA DANAE	0.1151
30-Sep-14	NH25	ACARTIA LONGIREMIS	0.0276
30-Sep-14	NH25	BARNACLES	0.0025
30-Sep-14	NH25	CALANUS PACIFICUS	0.0773
30-Sep-14	NH25	CALOCALANUS PAVO	0.0023
30-Sep-14	NH25	CALOCALANUS STYLIREMIS	0.0046
30-Sep-14	NH25	CALOCALANUS TENUIS	0.0125

30-Sep-14	NH25	CANDACIA BIPINNATA	0.0103
30-Sep-14	NH25	CHAETOGNATHA	0.0959
30-Sep-14	NH25	CLAUSOCALANUS ARCUICORNIS	0.0933
30-Sep-14	NH25	CLAUSOCALANUS PAULULUS	0.008
30-Sep-14	NH25	CLAUSOCALANUS PERGENS	0.0651
30-Sep-14	NH25	CORYCAEUS ANGLICUS	0.0008
30-Sep-14	NH25	CTENOCALANUS VANUS	0.1648
30-Sep-14	NH25	EUCALANUS	0.0023
30-Sep-14	NH25	EUPHAUSIA PACIFICA	2.3037
30-Sep-14	NH25	HETERORHABDUS PAPILLIGER	0.0335
30-Sep-14	NH25	LUCICUTIA	0.0251
30-Sep-14	NH25	MESOCALANUS TENUICORNIS	0.1146
30-Sep-14	NH25	METRIDIA	0.4639
30-Sep-14	NH25	OITHONA SIMILIS	0.1153
30-Sep-14	NH25	OITHONA SPINIROSTRIS	0.0161
30-Sep-14	NH25	PARACALANUS PARVUS	0.1032
30-Sep-14	NH25	PSEUDOCALANUS	0.1284
30-Sep-14	NH25	RADIOLARIANS	0
30-Sep-14	NH25	SCOLECITHRICELLA MINOR	0.0161
30-Sep-14	NH25	THYSANOESSA SPINIFERA	0.3105

Data was collected in September 2014, via the R/V Oceanus

MARINE MAMMAL SCIENCE PARTY INSTRUCTIONS

Make sure your party has copies of the marine mammal background sheet, the marine mammal data sheet, a blank map and three different colored pens.

1) Read your background sheet paying close attention to the most commonly found species of whales, dolphins and porpoises found in Oregon.
2) Your science party will be looking at a set of marine mammal survey data. These data are real and collected from the Oregon Coast. Locate your map.
    a. On your map, you will see three points labeled “NH05,” “NH15,” and “NH25.” These are stations along the Newport line where the CTD and Plankton Tow data were also collected.
3) Take a look at your data. This is a simplified view of marine mammal survey data. It has the species name, the latitude and longitude the animal was spotted at, and how many individuals were present.
4) On your map, locate the latitude and longitude lines. Begin to fill in the locations of where these animals were located. Decide on a system that shows what kind of animal it is, whether that’s a color, shape, labelling it, etc.
    a. Be sure to provide a key as well so others can interpret your completed map.
5) Once you have finished your map, get a blank graphing sheet. On the x-axis, list each of the species you identified on your map. On the y-axis, put numbers of individuals. Make a bar graph showing how many individuals of each species was recorded.
6) Discuss the following questions with your party:
    a. Does one species occur in a certain area more than another? If yes, why do you think that is?
    b. Pay attention to the location of the stations where CTD and plankton tow data were collected. Are there any species that seemed to gather near one of the sampling stations?

c. Do you see a species that was recorded that is not listed on the species chart on your background sheet? If yes, why do you think that is?

d. What are some other measurements the science team could make, other than just presence/absence data?

e. Why do you think this “presence/absence” data is important?

    i. What could it be used for?

f. Be prepared to give a brief overview to your classmates about what your science party did and found with your data. You should talk about:

    i. What your data set was

    ii. What your analysis task was

    iii. What the results are

    iv. Discuss any hypotheses you have or any questions

    v. Why you think it’s important to collect this type of data

MARINE MAMMAL SCIENCE PARTY BACKGROUND

- What species of marine mammals do we have in Oregon?

  The Oregon Department of Fish & Wildlife says that while there are nearly 80 species of whales, porpoises and dolphins, we have about 10 of those species that could be found in our waters.

GRAY WHALE	*Eschrichtius robustus*
BLUE WHALE	*Balaenoptera musculus*
MINKE WHALE	*Balaenoptera acutorostrata*
HUMPBACK WHALE	*Megaptera novaeangliae*
SPERM WHALE	*Physeter catodon*
PACIFIC WHITE SIDED DOLPHIN	*Lagenorhynchus obliquidens*
BOTTLE NOSE DOLPHIN	*Tursiops*
DALL’S PORPOISE	*Phocoenoides dalli*
HARBOR PORPOISE	*Phocoena phocoena*
KILLER WHALE	*Orcinus orca*

https://myodfw.com/wildlife-viewing/species/whales-dolphins-and-porpoises

- How are mammal surveys conducted?

  Usually, a researcher will stand somewhere they have a good view on all sides. Using binoculars or a spotting scope, they will observe the horizon until spotting something interesting, like a splash, to follow.

- What kind of things are collected on a marine mammal survey?

  “Presence/absence” data. This is documenting where the animals are located at any given time, and where they are not.

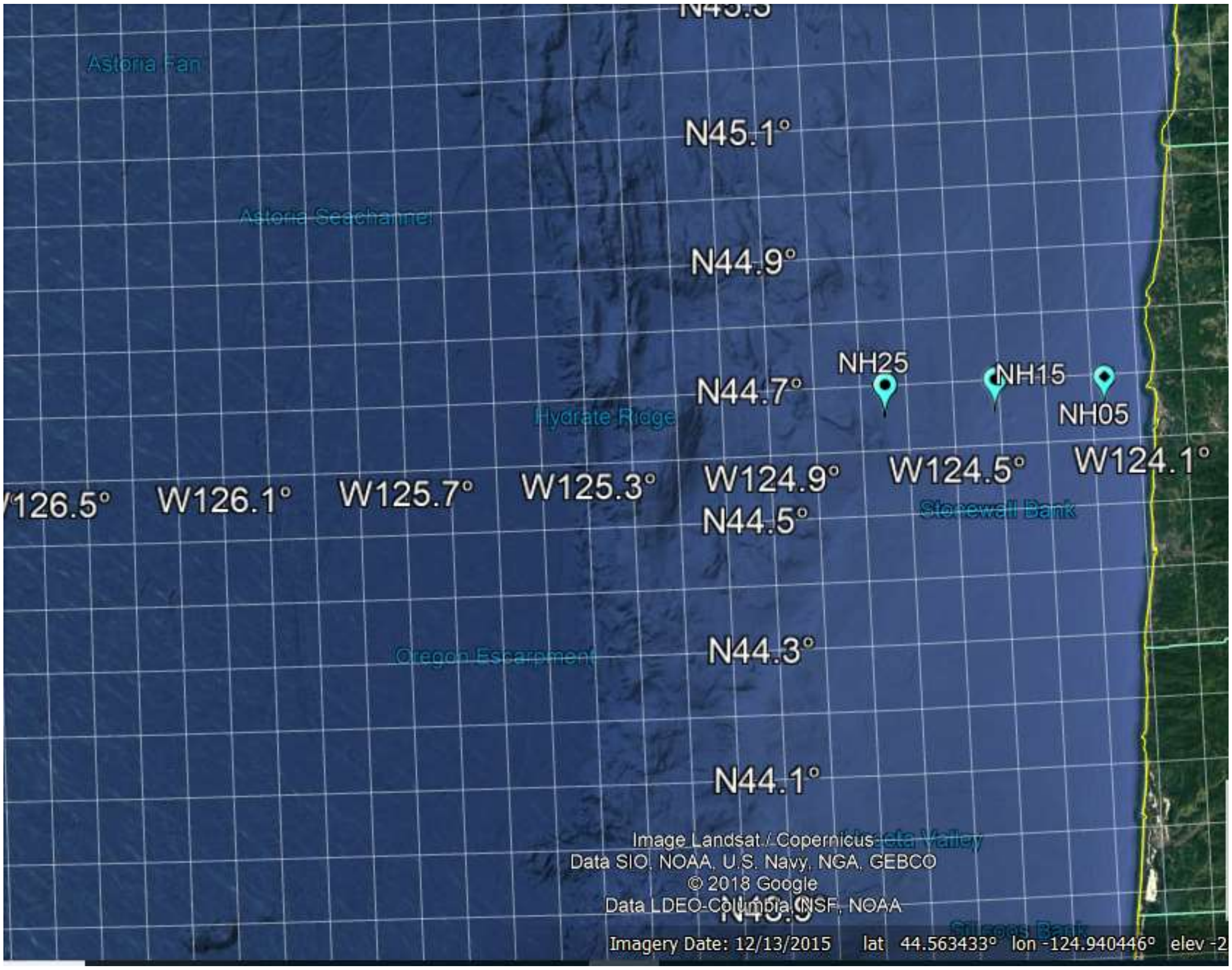
Other things that can be documented include variables like number of individuals, species or behavior (for example: feeding).

MARINE MAMMAL SCIENCE PARTY DATA

SPECIES	**LAT**	**LONG**	**GROUP SIZE**
Megaptera novaengliae	**-124.28**	**44.87**	**1**
Balaenoptera	**-124.28**	**44.91**	**1**
Balaenoptera	**-124.28**	**44.93**	**1**
Megaptera novaengliae	**-124.32**	**45.02**	**3**
Lissodelphis borealis	**-125.39**	**44.75**	**35**
Balaenoptera physalus	**-125.3**	**44.7**	**1**
Balaenoptera physalus	**-125.3**	**44.7**	**1**
Phocoenoides dalli	**-125.7**	**44.82**	**2**

Data was collected in 2014, via the Southwest Fisheries Science Center

MARINE MAMMAL SCIENCE PARTY MAP



Appendix D: Student Survey

Your opinions about science and learning activities

1. **Please circle a number that corresponds with your feelings about each statement.**

STATEMENT	STRONGLY DISAGREE	MODERATELY DISAGREE	SLIGHTLY DISAGREE	NEITHER	SLIGHTLY AGREE	MODERATELY AGREE	STRONGLY AGREE	I DON'T KNOW (Check box for this answer)
Science is the most interesting school subject	1	2	3	4	5	6	7	
Science is useful for everyone to learn	1	2	3	4	5	6	7	
I am comfortable working with data in class	1	2	3	4	5	6	7	
We have already explored most of the ocean	1	2	3	4	5	6	7	
I understand how data are collected by researchers	1	2	3	4	5	6	7	
I do **not** enjoy science learning through lectures with note taking	1	2	3	4	5	6	7	
I know how to tell if a source of scientific information is reliable or not	1	2	3	4	5	6	7	

STATEMENT	STRONGLY DISAGREE	MODERATELY DISAGREE	SLIGHTLY DISAGREE	NEITHER	SLIGHTLY AGREE	MODERATELY AGREE	STRONGLY AGREE	I DON'T KNOW (Check box for this answer)
I am comfortable with finding patterns in data	1	2	3	4	5	6	7	
An accepted scientific theory has been supported by evidence and has survived all attempts to disprove it .	1	2	3	4	5	6	7	
I would be okay with getting a C or lower grade in my science class	1	2	3	4	5	6	7	
The ocean can affect the weather around me	1	2	3	4	5	6	7	
Science is fun	1	2	3	4	5	6	7	
I can apply what I learn in science class to the real world.	1	2	3	4	5	6	7	
What happens in the ocean does **not** affect what happens to me	1	2	3	4	5	6	7	

STATEMENT	**STRONGLY DISAGREE**	**MODERATELY DISAGREE**	**SLIGHTLY DISAGREE**	**NEITHER**	**SLIGHTLY AGREE**	**MODERATELY AGREE**	**STRONGLY AGREE**	**I DON'T KNOW (Check box for this answer)**
It would be cool to be a scientist	1	2	3	4	5	6	7	
I enjoy learning science through hands-on activities, such as field trips	1	2	3	4	5	6	7	
I do ***not*** *know how researchers find answers from their data*	1	2	3	4	5	6	7	
I do ***not*** *want to study science in college*	1	2	3	4	5	6	7	
What we all do affects the ocean	1	2	3	4	5	6	7	
I enjoy figuring out challenging problems with data sets	1	2	3	4	5	6	7	
I look for scientific evidence before making decisions about important issues.	1	2	3	4	5	6	7	

2. Indicate on each of the following scales how you feel about *science in general*. (Circle one number for each measurement).

Dislike	1	2	3	4	5	Like
Bad	1	2	3	4	5	Good
Negative	1	2	3	4	5	Positive
Harmful	1	2	3	4	5	Beneficial

3. Indicate on each of the following scales how you feel about *learning science in school*. (Circle one number for each measurement).

Dislike	1	2	3	4	5	Like
Bad	1	2	3	4	5	Good
Negative	1	2	3	4	5	Positive
Harmful	1	2	3	4	5	Beneficial

4. Please indicate on each of the following scales how you would react to learning about marine mammals, for example, whales, dolphins or sea lions. (Circle one number for each measurement).

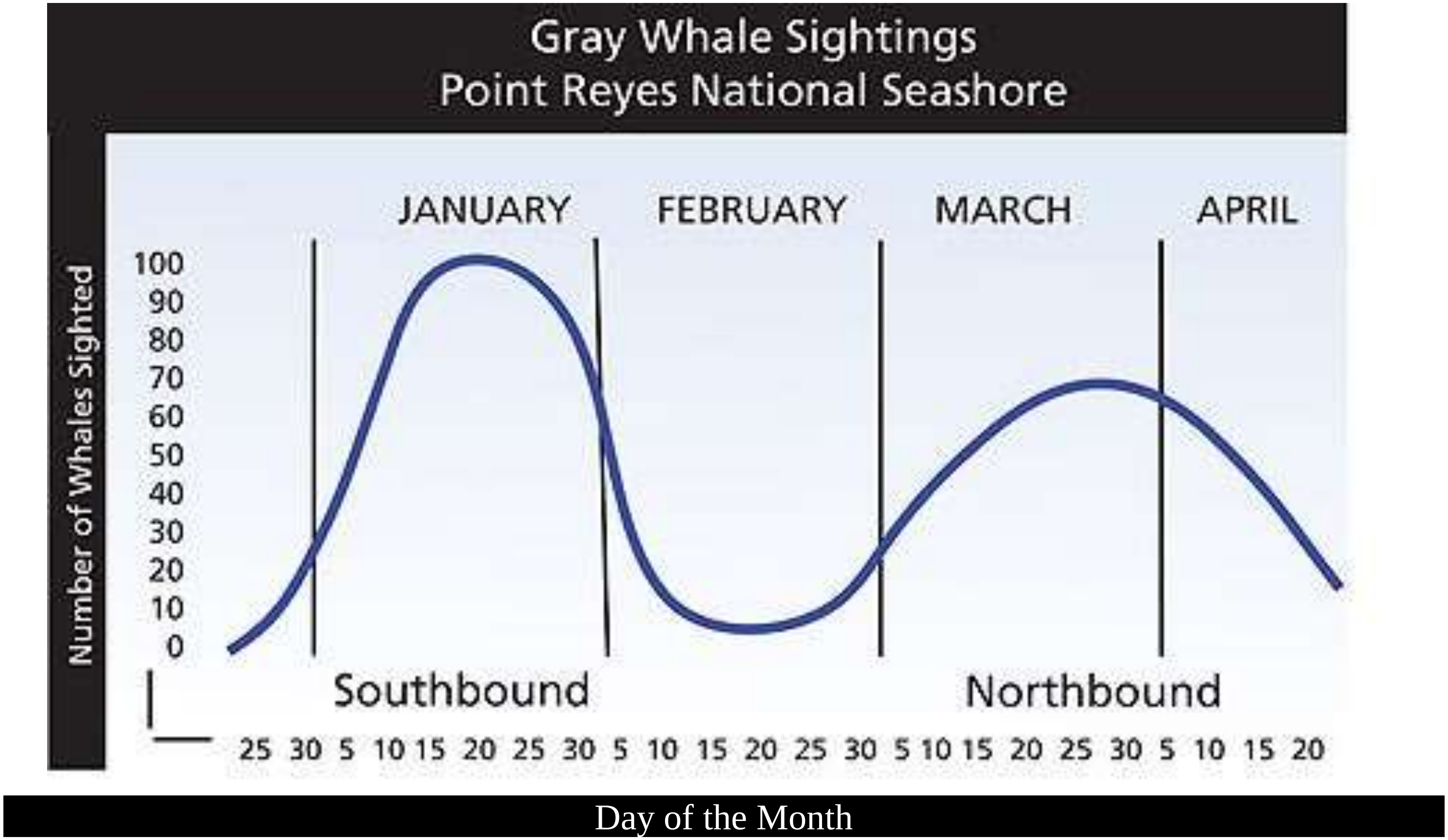
Unhappy	1	2	3	4	5	Happy
Not Excited	1	2	3	4	5	Excited
Not Curious	1	2	3	4	5	Curious
Frightened	1	2	3	4	5	Not Frightened
Angry	1	2	3	4	5	Not Angry

5. On Page 6, Figure 1 shows gray whale sightings over the course of one year. Please answer the following questions regarding Figure 1, to the best of your ability.

<u>Please explain the pattern shown by this figure</u>

<u>What do you think this represents?</u>

Figure 1: Number of gray whale sightings over the period of 1 year



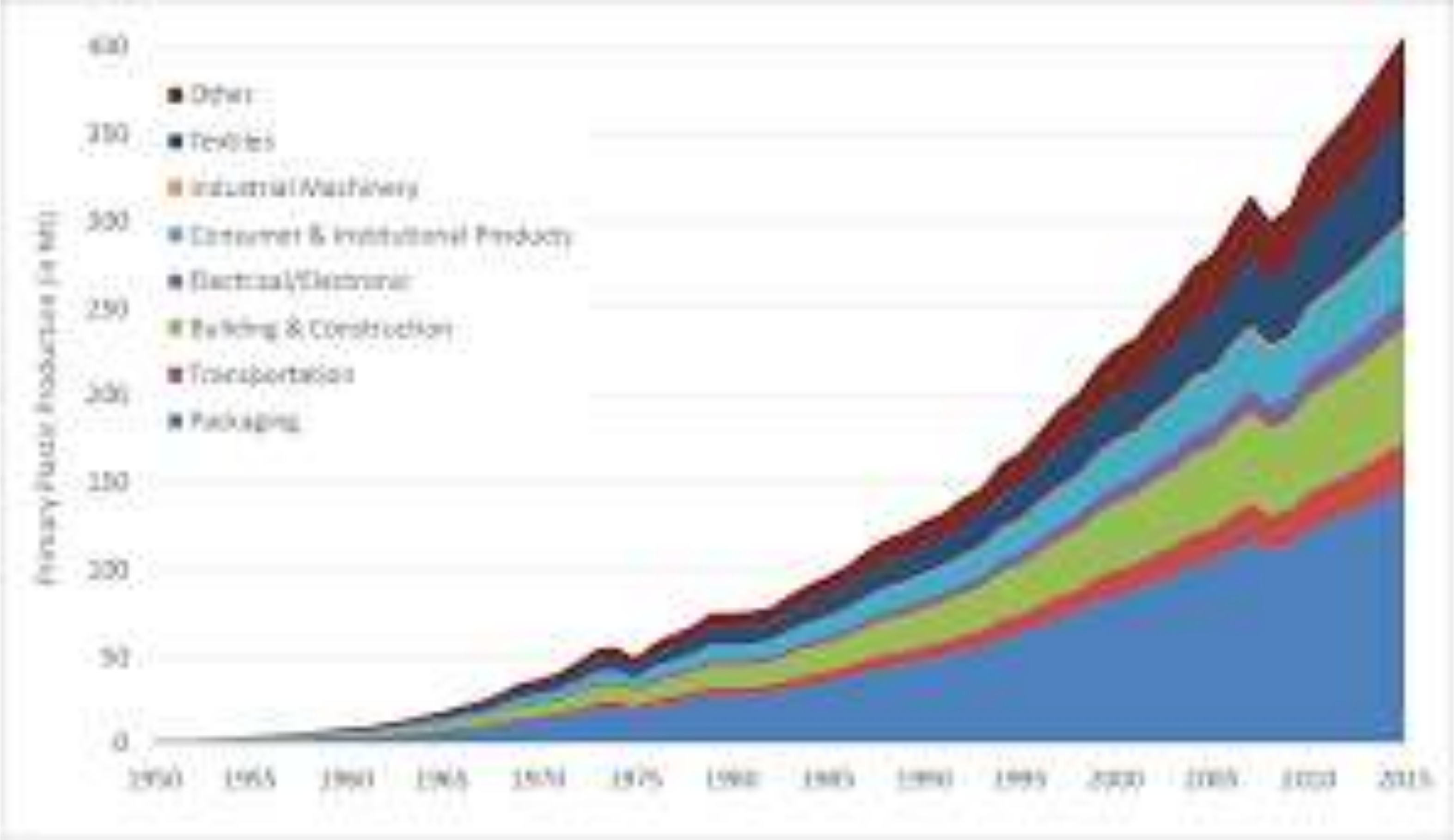
(Credit: National Park Service)

6. On Page 8, Figure 2 shows types of plastic waste generated over the course of 75 years. Please answer the following questions regarding Figure 2 to the best of your ability.

Please explain the common trend throughout this graph

What type of plastic waste is generated the most?

Figure 2: Global primary plastic waste generation (in million metric tons) according to industrial use sector from 1950 to 2015.



Year

(Credit: Geyer, Jambeck, Law, ‘Science Advances’ July 2017)

6. Please answer the following questions:

How would you describe yourself? (For example: Male, Female, Transgender): ________________________________

What grade are you in? (Check one) 9TH________ 10TH __________ 11TH_________ 12TH___________ OTHER __________

Thinking about your parent with the highest level of schooling, check which he or she has completed (Check one)

___ Less than 9th grade

___ 9th to 12th grade, but with no diploma received

___ High school graduate or equivalent (e.g., GED)

___ Some college, but with no degree received

___ Associates degree or 2-year technical degree

___ Bachelor’s degree

___ Graduate (e.g., masters, PhD) or professional degree (e.g,, law, medical doctor)

___ I don’t know what level of education my parents have had

How do you feel about each of the following science subjects? (Please circle a number that corresponds with your feelings about each subject).

SUBJECT	**STRONGLY DISLIKE**	**MODERATELY DISLIKE**	**SLIGHTLY DISLIKE**	**NEITHER**	**SLIGHTLY ENJOY**	**MODERATELY ENJOY**	**STRONGLY ENJOY**	**I DON'T KNOW (Check box for this answer)**
Biology	1	2	3	4	5	6	7	☐
Chemistry	1	2	3	4	5	6	7	☐
Physics	1	2	3	4	5	6	7	☐
Earth Science	1	2	3	4	5	6	7	☐
Environmental Science	1	2	3	4	5	6	7	☐
Astronomy	1	2	3	4	5	6	7	☐
Anatomy	1	2	3	4	5	6	7	☐

7. Please fill out the identification line below with your initials, along with the month and day you were born. (For example, Jane Doe was born on October 10th. Her line would say “JD1010”.) Please ask if you need further clarification.

____

FOR RESEARCHER USE ONLY – DO NOT FILL OUT

SURVEY # (1, 2, or 3) ___________
DATE ___________
TEACHER ___________
CLASS PERIOD _________
TREATMENT (VA, CA, CC) ______________

Thank you so much for agreeing to participate in this study. Your answers will provide valuable insight into different types of learning activities and their effects on high school students. This study is particularly focused on attitudes, emotions and beliefs toward science, in addition to data, science, and ocean literacy. Please answer honestly, there are no right answers and you will not be graded on these. Make sure to answer and fill out the final question (Question 7) correctly, as this will help us match each questionnaire to you. This should take approximately 15 minutes to complete. If you have any questions or concerns, please contact Graduate Student Research Danielle Miller (barbkned@oregonstate.edu) or Principal Investigator Tracy Crews (tracy.crews@oregonstate.edu). If you have questions about rights as a participant, contact the Oregon State University Institutional Board Office at: IRB@oregonstate.edu or 541-737-8008.