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Ocean Literacy Now Requires Data Literacy

RESEARCH AND EVALUATION

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ABSTRACT

New technologies are continually being placed in the ocean, constantly collecting data in real time. As a result, Data Literacy is now a necessary learning goal for supporting students' Ocean Literacy. The newest ships in the U.S. Academic Research Fleet, the Regional Class Research Vessels (RCRVs), are being built with the aim of supporting data literacy through outreach and education, with aid from a forthcoming real-time data portal. To understand how the RCRVs' outreach and education initiatives can best support data and ocean literacy, while also facilitating intentional engagement with minoritized populations, a three-phase research strategy was conducted over three years. The objective was to determine promising practices in data literacy education and shipboard outreach. The first phase of the research interviewed experts in the fields of teaching, data literacy, shipboard education, and community engagement in order to generate recommendations. The second phase was an assessment of a three-day data literacy high-school curriculum utilizing research vessel data. The third phase examined the success of potential culturally responsive data literacy curricular frameworks and teaching practices in an afterschool pilot program for Latinx youth. The research determined that as students have never-ending access to data, data literacy education must be scaffolded throughout a student's life. Data used in education must be contextual and relatable and the best tools for data literacy learning are designed for teachers and students. As new knowledge is generated about the ocean through new technologies continually collecting data, ocean literacy can no longer exist without data literacy.

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INTRODUCTION

The original ocean literacy framework has been essential to marine education since its original publication in 2005. The established principles are critical for guiding national education standards and curricula resources in order to facilitate a global understanding of ocean systems and human impacts. However, many people spend only a small part of their lives engaging with the ocean, despite marine education professionals recognizing that a significant driver of building ocean literacy is a sense of connectedness with the sea (Cigliano et al., 2015).

A potential solution to this problem is increasing access to technology. Computers and internet connectivity allow more people to connect and engage with marine issues. Oceanographic science is moving toward generating large quantities of information through technological systems, collecting and streaming data in real time or near real time. Scientists are placing an increasing number of scientific instruments, like buoy arrays and ARGO floats, into the sea or atmosphere to collect data on ocean phenomena. These technologies allow scientists to collect continuous data and data on previously unexplored areas in the sea. Modern ocean technologies have amassed an enormous quantity of data over the past thirty years, and many ocean scientists predict that most future discoveries will come from technological systems (Hey et al., 2009). Yet, a large quantity of the data collected from these new technologies sits in its raw form in repositories (Benway et al., 2019), which can be challenging to access and analyze without expert-level data literacy (DL) (Deahl, 2014).

As an increasingly large swath of ocean data is being collected by new technology, data literacy is becoming vital for understanding the ocean and generating new knowledge. As more knowledge about the ocean is created through massive data sets, student DL is invaluable for building ocean literacy. Yet, what exactly is DL? A standard definition of DL is the ability to "collect, evaluate, analyze and interpret data, present derived results, and take ethically sound action based on them" (Dichev & Dicheva, 2017, pg. 2153). DL intersects statistical, scientific, and computer literacy and is invaluable for all three in the modern age. Large data sets are often placed in repositories by multiple actors, including scientists, governments, and corporations, and much of it goes unanalyzed (Manyika et. al, 2011).

Many people in the United States struggle with basic scientific concepts despite having abundant access to data. There is a growing concern that the K-12 system may not adequately prepare 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 and recognizing credible and meaningful connections (Russell, & Weems, 2001; Schmar-Dobler, 2003). Today's students face numerous challenges: constant access to near-endless amounts of data, a significant inability to decipher that data, and a critical need to understand environmental data (Brem, Russell, & Weems, 2001; Finzer, 2013; National Academy of Sciences, 2007 ; Schmar-Dobler, 2003). Because of this, it is necessary to identify how we can best deliver and utilize oceanographic data in the classroom to support DL in pursuit of ocean literacy. In addition, it is especially valuable to identify how to deliver oceanographic data to the classroom in a way that is culturally responsive and equitable.

THE REGIONAL CLASS RESEARCH VESSEL PROJECT

Oregon State University (OSU) is set to become a greater producer of large-scale oceanographic data. In 2013, OSU was selected by the National Science Foundation (NSF) as the lead institution to oversee the design and construction of up to three new Regional Class Research Vessels (RCRVs). After Congress authorized full funding in 2018, the project solidified plans for the building and transition into operations of three ships for operations on the U.S. West, East, and Gulf coasts. These next-generation ships will have more advanced technological capabilities than previous research vessels, allowing both scientists and educators access to crucial real-time oceanographic data. The RCRVs are designed to be quieter, to use waste heat, and to have low atmospheric emissions, and they will significantly expand the capacity for marine science research in the coastal zones of the United States. OSU will receive the first new RCRV vessel, R/V *Taani* (Figure 1), which will operate on the West Coast as part of the Academic Research Fleet that is coordinated by the University-Oceanographic Laboratory System (UNOLS). The name *Taani* translates to "Offshore" in Siletz, a language of indigenous peoples whose traditional lands are on the Oregon coast. The R/V *Taani* will replace the retired OSU research vessel R/V

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Oceanus that operated for 45 years. The vessel will provide updated technology and at-sea comfort and safety for ocean scientists. Additionally, the R/V *Taani* and other RCRVs will have advanced datapresence systems streaming data to shore in real time.

Figure 1 Rendering of the R/V Tanni. Photo: Glosten Associates. Reproduced with permission from Oregon State University.

The term datapresence refers to the capability of live-streaming data from a suite of shipboard instruments, something not currently available in the existing UNOLS fleet. In older vessels, data are often collected, stored, taken back to a shore-based lab, then analyzed. The ability to transmit 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.

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 DL. The RCRV project brought together an education and outreach team to conduct research on how the RCRVs can best support DL education in the service of ocean literacy and how to do so in a way that is culturally responsive.

This research was conducted by two graduate students on the RCRV project who were funded over three years to study best practices in DL education. The goal was to determine how improving DL can help build student ocean literacy and how to ensure lessons and programming were equitable and inclusive, with the aim of answering the question as to how oceanographic data from the RCRVs can be utilized to support students' data and ocean literacy. The research included interviews with professionals and the development and testing of two curricular programs, which ultimately supported the idea that DL may in turn support ocean literacy, and a continuum of learning is needed to build DL throughout students' education.

A THREE-PHASE RESEARCH DESIGN

A three-year study, implemented in three phases, deepened understanding of DL in support of ocean literacy. The research began with interviews with experts to determine potential best practices for DL learning in order to understand how the RCRV project may support students. The results from the interviews then aided in developing a high school classroom curriculum designed to implement oceanographic data collected from research vessels to foster DL. Lessons learned from the first classroom intervention and additional interviews further influenced the development of an afterschool program for Latinx high school students to identify possible practices for providing culturally responsive DL learning. The interviews with experts combined with the two education interventions helped to pinpoint challenges and appropriate strategies

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for equitably building student DL, so that marine scientists and educators can support ocean literacy in conjunction with the advancement of data-streaming marine technology.

THEORETICAL FRAMEWORK FOR CULTURALLY RESPONSIVE DESIGN

Dr. Geneva Gay developed the theory and practice of Culturally Responsive Teaching, which states culture is a multi-dimensional component of a student and how they may learn (Gay, 2018). The teaching theory is a layered approach typically applied to classroom spaces by teachers (Muñiz, 2019). In her book, *Culturally Responsive Teaching*, Dr. Geneva Gay asserts that cultural content is one component of culturally responsive teaching and that "it should be combined with instructional strategies that emphasize inquiry, critique, and analysis, rather than the traditional preferences for rote memory and regurgitation of factual information (Gay, 2018, pg. 35)." Informal learning environments may be culturally responsive or relevant if intentionally designed (Simpkins et al., 2017). STEM (science, technology, engineering, and mathematics) curriculum can be culturally responsive if it validates a student's cultural knowledge and practices. Still, there is no certainty the curriculum will be culturally responsive if used by a teacher who may not apply the pedagogy in their teaching (Brown, 2017).

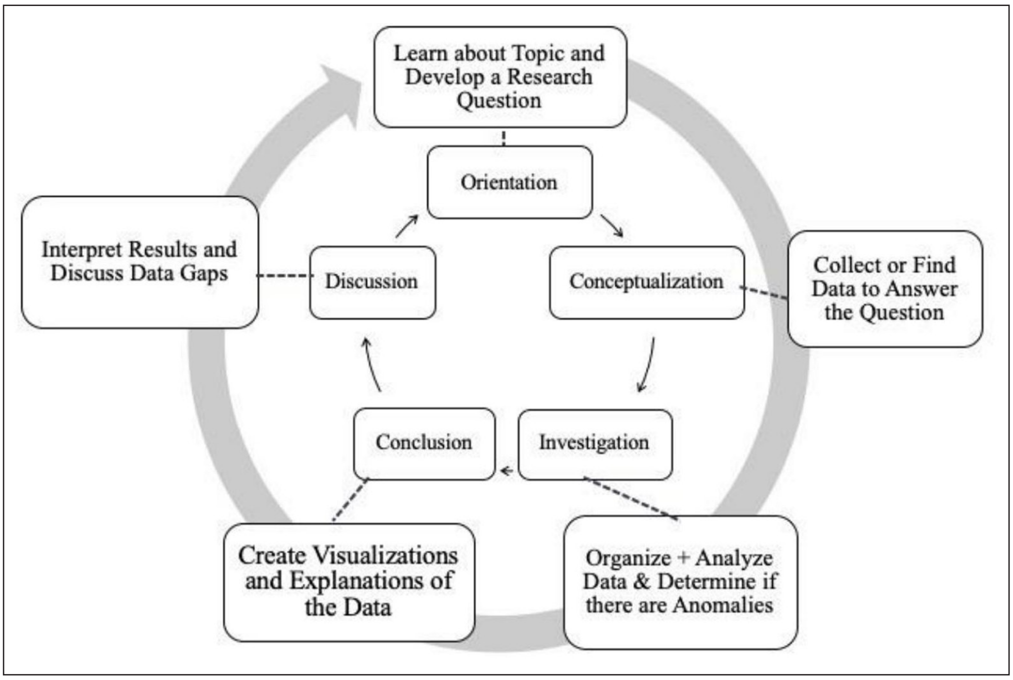

Figure 2 The Potential Coordination of the Data and Inquiry Cycles based on Pedase et. al. and definitions of data literacy.

Creative Data Literacy (CDL) was developed by the data feminist Catherine D'Ignazio as a strategy for teaching data equitably and meaningfully. In her paper on the subject, D'Ignazio outlines five tenets for teaching data creatively: (1) Work with community-centered data, (2) contextualize data through biographies or metadata, (3) make data messy, (4) build learner-centered tools, and (5) value community-driven outputs. Creative Data Literacy illuminates the disparity between experts and non-experts within data science and the necessity of building community DL as an emancipatory act in the age of Open Data (D'Ignazio, 2017).

A cycle of inquiry curricular model was selected as the best framework for supporting CDL, as inquiry-based science instruction emphasizes active participation, and students discover knowledge that is new to them (Pedaste et al., 2015). In an inquiry-driven lesson, students explore a phenomenon, develop hypotheses, collect and analyze data, present results, and draw conclusions from their results (Pedaste et al., 2015). The entirety of the lesson or curricula can be viewed as a cycle, commonly referred to as "The Cycle of Inquiry." While there are many descriptions of the Cycle of Inquiry, Pedaste et. al. synthesized and distilled the cycle into five phases: orientation, conceptualization, investigation, conclusion, and discussion (2015). The Cycle of Inquiry is potentially concomitant with the steps of the data process (Figure 2), which, as stated earlier, are a data literate person's ability to "collect, evaluate, analyze and interpret data, present derived results, and take ethically sound action based on them" (Dichev & Dicheva, 2017, pg. 2153).

METHODOLOGY

PHASE ONE: INTERVIEWS WITH PROFESSIONALS

Two cycles of interviews occurred over three years to determine best practices in DL learning within marine science and research vessel education. Forty-five interviews were conducted over the three years with professionals, including teachers, researchers, and professional development specialists. All professionals interviewed conduct work within the fields of DL, oceanography, and STEM learning.

The first cycle of interviews focused on identifying best practices in data literacy education through the perspectives of oceanographic researchers, high school teachers, and several professional development specialists. The second cycle of interviews expanded on the preliminary interviews by including DL experts, research vessel education specialists, and oceanographers whose work strongly incorporates justice, equity, diversity, and inclusion (JEDI). The second round of interviews examined DL education strategies that are inclusive, accessible, and equitable for minoritized populations. All interview participants were initially selected purposefully by identifying current experts in both DL and ship-based outreach and education (Yin, 2011). Recommendations and selections for additional people to interview were made by participants, resulting in the use of a Snowball Sampling protocol (Yin, 2011).

The design and analysis of the interviews 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). Interviews were conducted via telephone or in person, lasted an average of 30 minutes to an hour, and were transcribed and open-coded using the qualitative analysis software MAXQDA. Open-coding refers to a reiterative review process that involves rereading transcripts and highlighting key trends, words, or phrases associated with the research objective (Khandkar, 2009).

PHASE TWO: IMPLEMENTING RESEARCH VESSEL DATA-BASED CURRICULUM IN A HIGH SCHOOL SETTING

Informed by the expert interviews and a literature review, the research team developed a three-day curriculum that utilized oceanographic data collected by research vessels. The curriculum was carefully designed based on promising practices identified by the first round of interviews. The data chosen for the lessons had undergone quality control and was simplified, was free of errors and missing information, and provided concrete examples of how data directly impacts student lives and experiences.

To test the effectiveness of the curriculum, two classes of Oregon high school science students were assigned to an experiential learning group (ELG), and another two were assigned to a passive learning group (PLG). 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." 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 students retain, as students feel more connected with the course material. This can also result in students being more engaged in the classroom (Association for Experiential Education, n.d.; Guest, Lotze, & Wallace, 2015; Jelinek, 1998).

Both groups received the same introduction to oceanography and data lesson on day one. On day two, the ELG participated in a hands-on activity that required them to analyze, graph and interpret data and communicate results, 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 DL. Data literacy was

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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). Survey data were then analyzed using the quantitative software Statistical Program for the Social Sciences (SPSS).

PHASE THREE: FURTHER TESTING WITH A HANDS-ON AFTERSCHOOL PROGRAM FOR LATINX STUDENTS

To expand on lessons learned from the previous phase of the research, the last phase investigated the utility of hands-on learning over a more extended period as a strategy for building a student's DL. The curriculum was structured into an eight-week afterschool program for Latinx students to examine promising practices in Culturally Responsive DL education, identified from the literature and expert interviews (Nolan, Miller, Crews & Conway, 2020). Curricular frameworks that fit within Dr. Gay's theory were additionally applied during the curriculum development, namely CDL and the Cycle of Inquiry. Latinx students were selected as the target population, as the Latinx community in Oregon has been growing at a rate faster than the national average. The Latinx population now accounts for 23% of students enrolled in K-12 schools in the state and is the largest minoritized group in Oregon (Ruffenach et al., 2016). The afterschool program was brought to fruition with significant help from OSU's Juntos program, an organization that empowers Latinx students in their education, and the Bilingual Education Coordinator at the Oregon school where it was piloted. The lead researcher for phase three is a cisgender white woman and took her positionality into account throughout the study.

The curriculum focused on community-centered and actionable data that connects to the ocean: microplastics in the student's local watershed. Microplastics are an emergent issue that now permeates natural environments globally and with potential ill health effects on human beings (Manikkam et al., 2013). In this afterschool program, students developed research questions (Figure 3), built trawls to collect microplastics in their local creek, examined and sorted plastics under a microscope while filling out a datasheet, then analyzed and presented their data (Figure 4). Developed around the Cycle of Inquiry, this curriculum allowed students to take control of the scientific process.

The first tenet of CDL was applied by examining microplastics, an issue the students could learn more about and have the agency to take action on. The second tenet of providing context was implemented by reinforcing the importance of metadata and making sure students took metadata (date, time, location, etc.) throughout the program. Tenet three of CDL was fulfilled as the process of student-collected data is inherently messy, so students were able to fully realize the strengths and weaknesses of their data. Tenet four of CDL, utilizing learner-centered tools, refers to analysis and visualization tools. To fulfill tenet four, the online software TuvaLabs was utilized in the data analysis. This software is learner-friendly and does not require significant domain expertise. It was also made freely available for teachers during the COVID-19 pandemic for a limited time.

To fulfill the fifth tenet, valuing community-centered output, students were given multiple options for presenting their data in a framework of "community-centered output." Students were introduced to data sculptures, data art, data music videos, and scientific posters. They worked as a group to determine which output they wanted to collaborate on together. Ultimately, the participating students decided they wanted to create a scientific poster together, in order to learn a skill that may be useful for them in college (Figure 4). After the data cycle was complete, they then came up with more hypotheses based on their results (Figure 4). In the final lesson, they were introduced to and explored large ocean databases.

In the pilot of the afterschool program, seven students from the Latinx community enrolled, and six regularly participated. Five of the six regularly participating students were recent immigrants to the United States, and one was U.S.-born. Four students were from Chile, one was from Peru, and the U.S.-born student's parents were from Mexico. Spanish was the first language of all of the students, and all of them expressed a desire to be scientists or doctors when they grew up.

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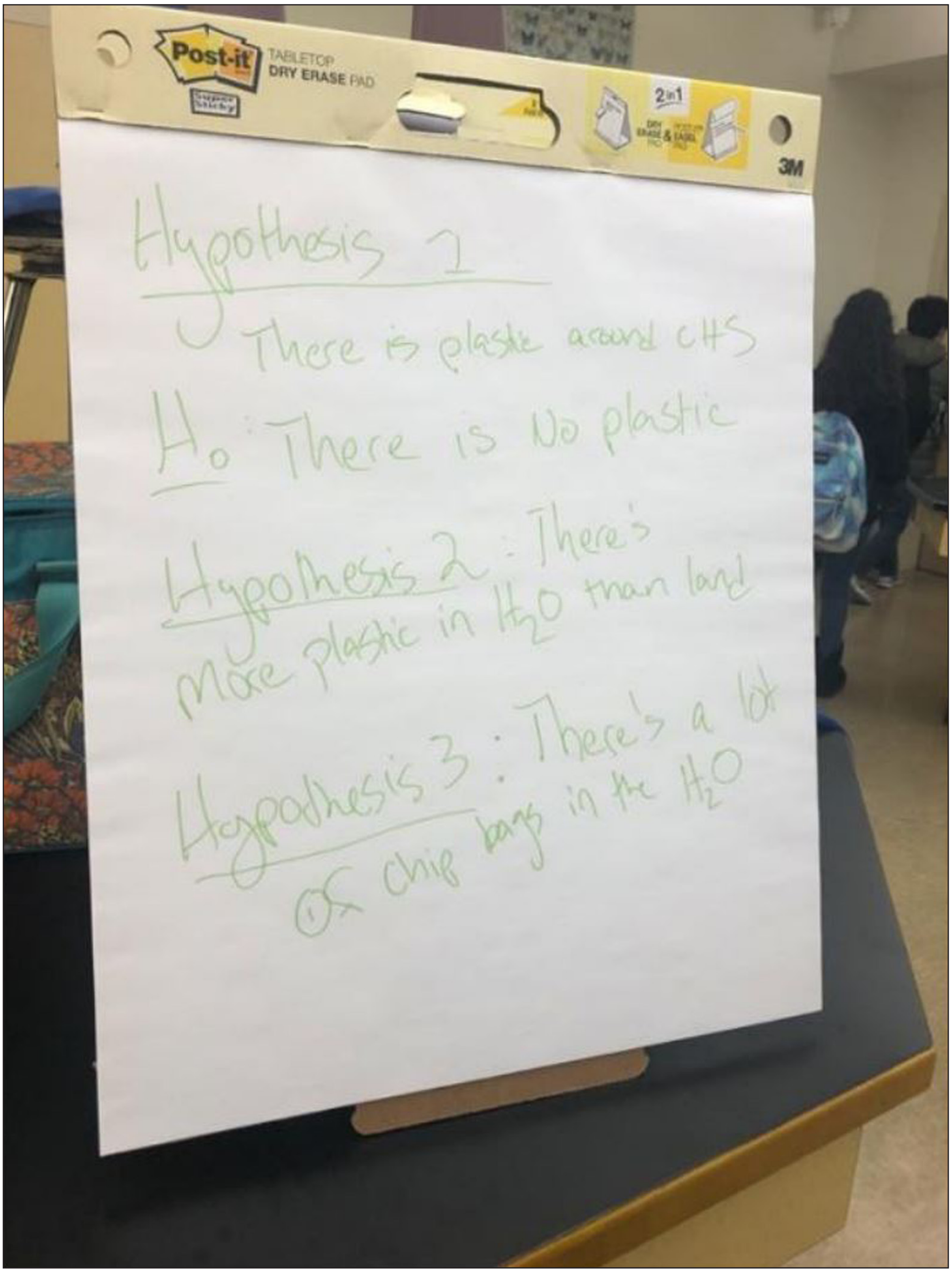

Figure 3 Student Generated Hypotheses from the Aferschool Program Prior to Data Collection. Photo: Hannah Nolan.

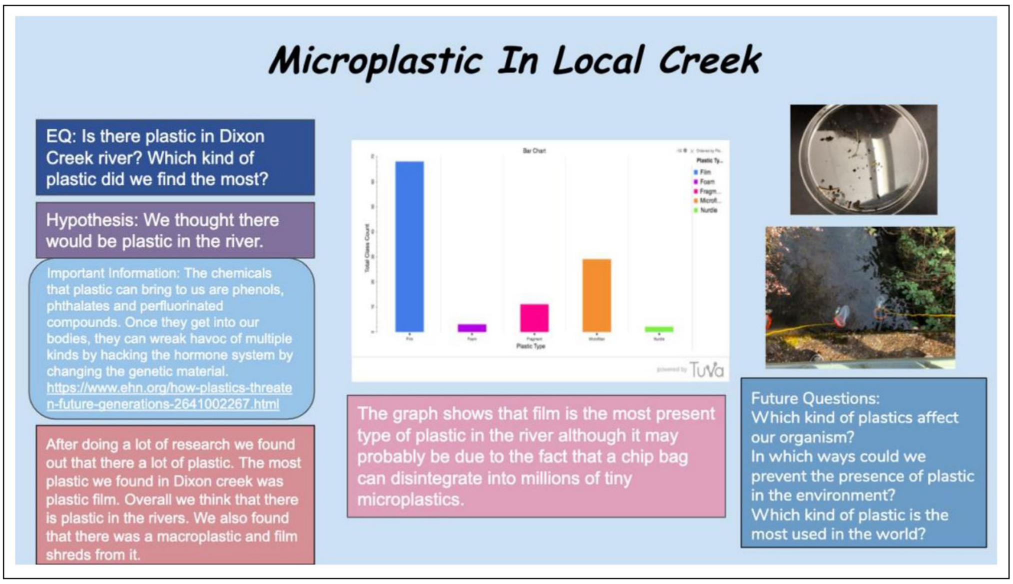

Figure 4 Collaboratively Generated Student Research Poster from the Mar Adentro Program. Students created this in a 45-minute period online during the COVID-19 Pandemic.

To determine the pilot program's effectiveness, a qualitative study was utilized. Data included pre and post surveys and pre and post interviews. The researcher took reflective notes after each lesson ended. The program lasted longer than the originally planned eight weeks, to provide additional support to the students in the early weeks of the pandemic.

RESULTS

Over three years, three phases of research elucidated the importance of DL in supporting ocean literacy. The expert interviews aided in developing a classroom curriculum, and lessons learned from the classroom intervention further influenced the development of an afterschool program. Overall, this research helped to identify the following challenges and appropriate strategies for building student DL, so that marine scientists and educators can support ocean literacy in conjunction with the advancement of marine technology and data science in a way that is equitable and inclusive.

PHASE ONE RESULTS

The researchers determined several themes through the interviews, which informed the development of a plan for equitable and inclusive DL education supported by the RCRV Project. The complete list of recommendations is viewable in *Promising Practices and Considerations for RCRV Outreach and Education: Lessons Learned from Research on How the Next Generation of Regional Class Research Vessels Can Support Equitable Data Literacy Education*.

The interviews helped clarify the support needed for the successful transfer of 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 research provided context on teacher needs to inform the design and implementation of phase two. After finishing data analysis in phase one, it was determined that for an effective DL curriculum, students require relevant, consistent, clearly formatted canned data in addition to real-time data, for the best potential impacts on student DL.

PHASE TWO RESULTS

Ultimately, there was a lack of significant results linking the use of real data in an experiential learning setting to increased DL. However, the lack of significant results originating from the ELG does not necessarily negate a link between them. Instead, the results highlighted a set of underlying issues that must be addressed, including a lack of preexisting DL and limited instruction time.

Per the Next Generation Science Standards, students entering the ninth 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 instructional 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 highlights the challenges high school teachers often face when attempting to utilize data in their classrooms. 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).

The identification of factors impacting the successful implementation of data-based, hands-on curriculum prompted further investigation in the next phase of the research. This final phase was designed to utilize previously collected information to further understand best practices for DL and determine promising strategies for creating culturally responsive programming.

PHASE THREE RESULTS

All participating students entered the program with high-level DL for their age as determined by the pre-survey. The students all successfully interpreted a CTD (conductivity, temperature, depth) graph and growth in plastic production graph, and were able to successfully create their own graphs. After participating in the pre-survey and interviews the students then went through an eight-week curriculum. The eight-week program introduced them to the data process, microplastics, and their watershed. As the students came up with easily testable questions, they were able to confirm their hypotheses and found microplastics in their local creek. Interviews and surveys determined they emerged from the program understanding their one day of data collection was not enough to make firm conclusions. None of them had heard about microplastics before the program, and all ended the program feeling concerned about it. In the pre-survey, students were asked what their primary environmental concern was. All of them responded with climate change. The students were asked the same question in the post-survey and four changed their answer to plastic in the environment. At the end of the program, one student said he wanted to go to college to study microplastics and their chemical effects on humans.

Overall, the results indicated that the collaborative, hands-on program was a positive experience for the students. They enjoyed learning that science was collaborative and felt empowered after learning how to collect and analyze their own data. The students also expressed that they enjoyed learning about science with other Spanish first-language peers, as they could communicate about science in their first language.

DISCUSSION

The three-phase research design ultimately determined that DL is a complex literacy that must be built through each grade level, and that ocean data has the potential to support this learning. The following outcomes were identified over the three years as best practices for teaching oceanographic data: building DL, facilitating culturally responsive DL learning, and supporting educators with data in the classroom.

DATA TOOL DESIGN AND USABILITY

Many of the teachers interviewed stated they prefer a website-focused approach to accessing ocean data and educational resources during their interviews. However, many said existing data portals are inaccessible and difficult to navigate. The interviews indicated data portals often take too much time to find, are poorly organized, lack usable information, and rarely offer additional user help. These features are necessary for data to be usable to teachers and their students. If programmers do not design data portals with teachers and students in mind, there is little chance the portal will be used in the classroom.

LACK OF EXISTING DATA SKILLS

The first round of curriculum testing in the classroom did not result in an improvement in student DL after completing the education intervention. However, it did highlight a set of underlying issues that need to be addressed, primarily a lack of existing DL in students.

Students struggled with basic graphing and mapping concepts, which meant the original timeline set for the activities was not 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 the students lacked. Because of this, students did not work with near-real-time data and were given additional time to allow for individual and group processing, sense-making, and communicating their results. While the lack of significant results stemming from the ELG was somewhat unexpected, the implementation of this education module revealed the various challenges teachers expressed to the researchers 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.

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Results from the afterschool program showed that participating students were adept at creating and analyzing graphs but did not realize how much time and effort it takes for scientists to collect data and make decisions based on data. The students also struggled to understand the large ocean databases shown in the final lesson.

SINGLE INTERVENTIONS ARE INSUFFICIENT

During the first curriculum implementation, it was clear that instructional time must be longer than three days to accomplish the identified educational goals. As it was initially written, the module did not result in the robust learning necessary to increase DL and affected students' positive attitudes and beliefs in their skills. Ideally, students need better preparation at each educational level and have 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 understanding, 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 insufficient instructional time can potentially impact Oregon students as they progress through their education, as they are not receiving the foundational science concepts and skills as they should be (Blank, 2012).

While the afterschool program helped build students' awareness of data and the data process, it did not significantly increase their ocean literacy. The students ended the program with an understanding of how their watershed connects to the ocean and how most plastic ends up in the sea. However, when students had the opportunity to examine large ocean databases, they felt confused and challenged, had to be taught additional ocean concepts, and struggled to complete the activity.

STRATEGIES

Research determined the following is necessary for DL education to address the identified challenges: (1) education must be scaffolded, (2) curricular data must be contextualized and relatable for students, and (3) software tools for DL should be explicitly created for classroom use. The listed strategies align with methods for making DL education culturally responsive, alongside closely working with minoritized community members and leaders when developing and implementing programming.

SCAFFOLDING

The data process is a cycle that includes: developing a research question, creating data collection and storage protocols, collecting data, analyzing data, presenting data, and then developing a new testable question. Learning how to develop the skills for each of these steps takes time and effort. For students to be able to utilize and understand data streaming from ocean technologies, their DL skills need to be facilitated from an early age. When working with students, they must understand that knowing how to do each step in the data process is a skill. A curriculum that isolates a step in the data process, or moves students through the entire data process, can be an effective tool for helping them understand its value.

Data literacy must build throughout a student's education, from kindergarten through college. Just like how turning data into information is a process, students understanding each step of the process takes time. In the evolving world of technology, a student cannot become data literate with a stand-alone education intervention. A student must develop DL as they move through their education. Learning how to develop the skills needed for each step in the data process takes time and effort, and knowing how to execute each step accurately itself is a skill. The afterschool program demonstrated the effectiveness of scaffolding the data process, as it isolated each step and explained the necessity of each step to the students. At the end of the program, students understood that generating knowledge from data takes significant time. One day of fieldwork and one data set is not sufficient for drawing scientific conclusions.

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CONTEXTUAL AND RELATABLE

Data used for education must be contextual, consistent, and relatable. Data without context is essentially meaningless. To be data literate, students must comprehend how and why people collect data and that specific protocols exist for collection. Data is ultimately a human construct, which we use to understand our world better. Even large data sets use numbers collected and analyzed through algorithms created by humans. Several professionals interviewed during the research suggested educational datasets should include "a data biography" or information about the people who collected the data, why they collected them, and why they chose certain collection protocols. Overall, many participants suggested that student-led research projects are vital for helping provide context because they support students' understanding of data collection. Other strategies for providing context include developing data dictionaries, which are explanations of metadata, and acronyms within a dataset.

Alongside providing context, education data should be relatable for the students, holding some sort of meaning for students working with it. Whether that means it is local, place-based data or the data has a clear connection to students or issues they care about, data needs to tell a story. Without that story, students may not be interested, and it would not be considered a "good data set" for use in education. Oceanographic data used in lesson plans intended to build ocean and DL should tell a pertinent story so that students understand the importance and are more deeply engaged.

One of the best strategies for making data relatable is data-driven research projects addressing local community issues. The use of community data can be especially pertinent for engaging minoritized populations (Deahl 2014; D'Ignazio, 2017). Participatory action research in which students can use data to make informed decisions or change within their communities supports effective DL lessons (Deahl, 2014; D'Ignazio, 2017). In addition, it is also believed that data activities that empower a student to impact change in their community may be one of the best strategies for building DL and can align with the principles of culturally responsive teaching. There are topics like local watersheds, bird migration, and climate change that can be used for ocean data learning no matter the students' proximity to the sea.

The afterschool curriculum demonstrated the impact of collecting data on relevant topics where students have the potential to influence change. Interviews, surveys, and student-generated work suggested all the students emerged with a greater understanding of the utility of data for making decisions that could result in positive change.

TOOLS FOR TEACHERS

The research determined that data portals designed for scientists are not usually effective tools for the classroom, as they are developed for people with expert-level knowledge as opposed to students who are just beginning to learn. Working with repository data often requires coding and software skills. While understanding programs like R, ArcGIS, and Python are now relevant skills for a career in science, a student must be trained to understand and use them first, and not all educators can be expected to teach these skills. To facilitate DL education, educators should have access to easy-to-use software. Effectively designed sites can allow us to bring real-world research experience to teachers and their students (McLaughlin, 2010). Additionally, utilizing software showcasing authentic data can promote deeper learning of science and math concepts and foster engagement using real-world investigations (McKay et al. 2007). TuvaLabs and Tableau were determined to be useful on-the-market software based on interviews and use in curriculum interventions.

ENSURING CULTURAL RESPONSIVENESS

Building and maintaining relationships with leaders from communities that have historically been locked out of ocean science and most STEM professions, such as Black, Latinx, and Indigenous communities, is vital for creating programming and curricular resources relevant to youth from these communities. Leaders embedded in these communities are better equipped to support the development of effective relationships with stakeholders from the community and to recruit youth to ocean science learning experiences. These leaders may also possess a clearer understanding of the topics and activities students may respond to positively (Bevan, Calabrese & Barton, 2018). As previously stated, the last phase of the research would have been unsuccessful without partnering with community leaders and liaisons.

Incorporating the first language of English second-language students was also found to be imperative for creating a culturally responsive environment. Students in the afterschool program interacted with the instructor primarily in English and communicated with each other in Spanish. The Latinx students all expressed the value of having a space where they could learn about science with other Spanish first-language students and communicate about science in their first language. While the six actively participating students all had a strong interest in science, many did not know one another before the program, and several expressed feeling excited to have met other Latinx students with an interest in science at the program's conclusion.

CONCLUSION

The ocean is now interlaced with numerous technologies constantly collecting data. Students require new skills to gain further insight and understand the ocean's mysteries. As we transform how we understand the sea, we must also change how we teach about it. Ocean literacy can no longer exist without understanding the data process as data-streaming technology becomes the primary tool for exploring our ocean. While this presents challenges for teachers working to build ocean literacy in their students, it also presents opportunities. Technologies now exist to connect students virtually with the ocean, which could be especially useful for students with few opportunities to connect with the ocean physically. DL can support ocean literacy by using practical tools developed for the classroom that engage students with contextualized and relatable data. We can scaffold the data process for students, showing them that creating knowledge from data is a messy, lengthy process. Hands-on learning opportunities where students have the opportunity to collect, analyze, and interpret data for their own research projects can be valuable for understanding the complexity of the data process and ocean issues. Working alongside community leaders, utilizing local, actionable, and culturally-relatable data, as well as providing materials and spaces for English second-language students to communicate about science in their first language, will ensure that data and ocean literacy learning is culturally responsive. Through building DL skills through the lens of ocean literacy, there is a unique opportunity to prepare students for STEM careers, as well as facilitate the next generation of informed community members and ocean advocates.

ADDITIONAL FILES

The additional files for this article can be found as follows:

- **Supplementary file 1.** Technical Report. Nolan, H., Miller, D., Crews, T., & Conway, F. (2020). *Promising practices and considerations for RCRV outreach and education: Lessons learned from research on how the next generation of regional class research vessels can support equitable data literacy education*. Oregon State University. DOI: https://doi.org/10.5334/cjme.78.s1
- **Supplementary file 2.** Graduate Thesis. Miller, D. N. (2019). The Data Stream: Assessing the Flow of Real Time Marine Science Data from Research Vessel to the Classroom. DOI: https://doi.org/10.5334/cjme.78.s2
- **Supplementary file 3.** Graduate Thesis. Nolan, H. L. (2020). Democratizing the Data Stream: Creating an Equitable Transfer of Research Vessel Data from Scientist to Student. DOI: https://doi.org/10.5334/cjme.78.s3

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COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR CONTRIBUTIONS

Phase One research design and interviews were designed and conducted by both Danielle Miller and Hannah Nolan. Phase Two was designed and implemented by Danielle Miller. Phase Three was designed and implemented by Hannah Nolan.

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REFERENCES

Andersen, S. C., Humlum, M. K., & **Nandrup, A. B.** (2016). Increasing instruction time in schooldoes increase learning. *Proceedings of the National Academy of Sciences of the United States of America, 113*(27), 7481–4. DOI: https://doi.org/10.1073/pnas.1516686113

Association for Experiential Education. (n.d.). *What is Experiential Education?* https://www.aee.org/what-is-ee

Benway, H. M., Lorenzoni, L., White, A. E., Fiedler, B., Levine, N. M., Nicholson, D. P., Degrandpre, M. D., Sosik, H. M., Church, M. J., O'brien, T. D., Leinen, M., Weller, R. A., Karl, D. M., Henson, S. A., & **Letelier, R. M.** (2019). Ocean time series observations of changing marine ecosystems: An era of integration, synthesis, and societal applications. *Frontiers in Marine Science, 6*. DOI: https://doi.org/10.3389/fmars.2019.00393

Bevan, Calabrese Barton & **Garibay.** (2018). *Broadening Perspectives on Broadening Participation in STEM: Critical Perspectives on the Role of Science Engagement*. Washington, DC: Center for Advancement of Informal Science Education.

Blank, R. K. (2012). *What Is the Impact of Decline in Science Instructional Time in Elementary School? Time for Elementary Instruction Has Declined, and Less Time for Science Is Correlated with Lower Scores on NAEP*. http://nces.ed.gov/surveys/sass/tables/sass0708_005_t1n.asp

Brem, S. K., Russell, J., & **Weems, L.** (2001). Science on the Web: Student Evaluations of Scientific Arguments. Discourse Processes, *32*(2–3), 191–213. DOI: https://doi.org/10.1080/0163853X.2001.9651598

Brown, J. C. (2017). A metasynthesis of the complementarity of culturally responsive and inquiry-based science education in K-12 settings: Implications for advancing equitable science teaching and learning: CRP AND INQUIRY-BASED SCIENCE METASYNTHESIS. *Journal of Research in Science Teaching, 54*(9), 1143–1173. DOI: https://doi.org/10.1002/tea.21401

Cigliano, J. A., Meyer, R., Ballard, H., Freitag, A., Phillips, T. B., & **Wasser, A.** (2015). Making marine and coastal citizen science matter. *Ocean & Coastal Management, 115,* 77–87. ISSN 0964-5691. DOI: https://doi.org/10.1016/j.ocecoaman.2015.06.012

D'Ignazio, C. (2017). Creative data literacy: Bridging the gap between the data-haves and data-have nots. *Information Design Journal, 23*(1), 6–18. DOI: https://doi.org/10.1075/idj.23.1.03dig

Deahl, E. (2014). *Better the data you know: Developing youth data literacy in schools and informal learning environments* (Master's Thesis, MIT, Boston US). MIT Libraries. http://hdl.handle.net/1721.1/89958. DOI: https://doi.org/10.2139/ssrn.2445621

Dichev, C., & **Dicheva, D.** (2017). Towards data science literacy. *Procedia Computer Science, 108*, 2151–2160. DOI: https://doi.org/10.1016/j.procs.2017.05.240

Finzer, W. (2013). The Data Science Education dilemma. *Technology Innovations in Statistics Education*, *7*(2). DOI: https://doi.org/10.5070/T572013891

Gay, G. (2018). *Culturally responsive teaching: Theory, research, and practice* (3rd ed.). Teachers College Press.

Guest, H., Lotze, H. K., & **Wallace, D.** (2015). Youth and the Sea: Ocean Literacy in Nova Scotia, Canada. *Marine Policy*, *58*, 98–107. DOI: https://doi.org/10.1016/j.marpol.2015.04.007

Hamer, L. O. (2000). The additive effects of semistructured classroom activities on student learning: An application of classroom-based experiential learning techniques. *Journal Of Marketing Education*. http://journals.sagepub.com/doi/pdf/10.1177/0273475300221004. DOI: https://doi.org/10.1177/0273475300221004

Hey, T., Tansley, S., & **Tolle, K.** (2009). *The Fourth Paradigm: Data-Intensive Scientific Discovery*. Microsoft Research. https://www.microsoft.com/en-us/research/publication/fourth-paradigm-data-intensive-scientific-discovery/

Jelinek, D. J. (1998, April 21). *Student Perceptions of the Nature of Science and Attitudes towards Science Education in an Experiential Science Program*. Institute of Education Sciences. https://eric.ed.gov/?id=ED41887

Khandkar, S. H. (2009). *Open coding*. University of Calgary. https://pages.cpsc.ucalgary.ca/~saul/wiki/uploads/CPSC681/open-coding.pdf

Likert, R. (1932). A technique for the measurement of attitudes. *Archives of psychology*.

Manikkam, M., Tracey, R., Guerrero-Bosagna, C., & **Skinner, M. K.** (2013). Plastics derived endocrine disruptors (BPA, DEHP and DBP) induce epigenetic transgenerational inheritance of obesity, reproductive disease and sperm epimutations. *PLoS ONE*, *8*(1). DOI: https://doi.org/10.1371/journal.pone.0055387

Manyika, J., Chui, M., Brown, B., Bughin, J., Dobbs, R., Roxburgh, C., & **Hung Byers, A.** (2011). *Big data: The next frontier for innovation, competition, and productivity*. McKinsey. https://www.mckinsey.com/~/media/mckinsey/business%20functions/mckinsey%20digital/our%20insights/big%20data%20the%20next%20frontier%20for%20innovation/mgi_big_data_exec_summary.pdf

McKay, S., Lowes, B., McGrath, P., Lin, E., Leach, M. (2007). *USE OF REAL-WORLD DATA AND INFORMATION IN THE CLASSROOM Evolution of a K-14 Teacher Preparation Model*. https://www.league.org/sites/default/files/private_data/imported/league_books/RWDataClassroom.pdf

McLaughlin, J. S. (2010). A multimedia learning tool that allows high school teachers and their students to engage in scientific research. *Technology Leadership in Teacher Education: Integrated Solutions and Experiences* (pp. 83–110). DOI: https://doi.org/10.4018/978-1-61520-899-9.ch006

Miller, D. (2019). *The Data Stream: Assessing the Flow of Real Time Marine Science Data from Research Vessel to the Classroom*. Oregon State University.

Muñiz, J. (2019, March 29). *Culturally Responsive Teaching: A 50-State Survey of Teaching Standards* (pp. 1–53, Rep.). New America. https://files.eric.ed.gov/fulltext/ED594599.pdf

Nolan, H. (2020). *Democratizing the Data Stream: Creating an Equitable Transfer of Research Vessel Data from Scientist to Student*. Oregon State University.

National Academy of Sciences, N. A. of E. and I. of M. (2007). *Rising above the gathering storm: Energizing and employing america for a brighter economic future*. (1st ed.). National Academies Press.

Next Generation Science Standards. (n.d.). *Read the Standards*. https://www.nextgenscience.org

Nolan, H., Miller, D., Crews, T., & **Conway, F.** (2020). *Promising practices and considerations for RCRV outreach and education Lessons learned from research on how the next generation of regional class research vessels can support equitable data literacy education.* Oregon State University. https://oregonstate.app.box.com/s/jp64xrd32opletg6ob2ujjoxblcotrjy

Pedaste, M., Mäeots, M., Siiman, L. A., de Jong, T., van Riesen, S. A. N., Kamp, E. T., Manoli, C. C., Zacharia, Z. C., & **Tsourlidaki, E.** (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review*, *14*, 47–61. DOI: https://doi.org/10.1016/j.edurev.2015.02.003

Rivkin, S. G., & **Schiman, J. C.** (2015). Instruction time, classroom quality, and academic achievement. *The Economic Journal*, *125*(588), F425–F448. DOI: https://doi.org/10.1111/ecoj.12315

Ruffenach, C., Worcel, S., Keyes, D., & **Franco, R.** (2016, August). *Latinos in Oregon: Trends and Opportunities in a Changing State*. Oregon Community Foundation. https://oregoncf.org/assets/PDFs-and-Docs/PDFs/latinos_in_oregon_report_2016.pdf

Schmar-Dobler, E. (2003). Reading on the Internet: The Link between Literacy and Technology. *Journal of Adolescent & Adult Literacy*, *47*(1), 80-85. https://doi.org/10.2307/40026906

Simpkins, S. D., Riggs, N. R., Ngo, B., Vest Ettekal, A., & **Okamoto, D.** (2017). Designing Culturally Responsive Organized After-School Activities. *Journal of Adolescent Research*, *32*(1), 11–36. DOI: https://doi.org/10.1177/0743558416666169

Walker, D., & **Myrick, F.** (2006). Grounded theory: An exploration of process and procedure. *Qualitative health research*, *16*(4), 547–559. DOI: https://doi.org/10.1177/1049732305285972

Yin, R. K. (2011). *Qualitative research from start to finish* (2nd ed.). The Guilford Press.

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