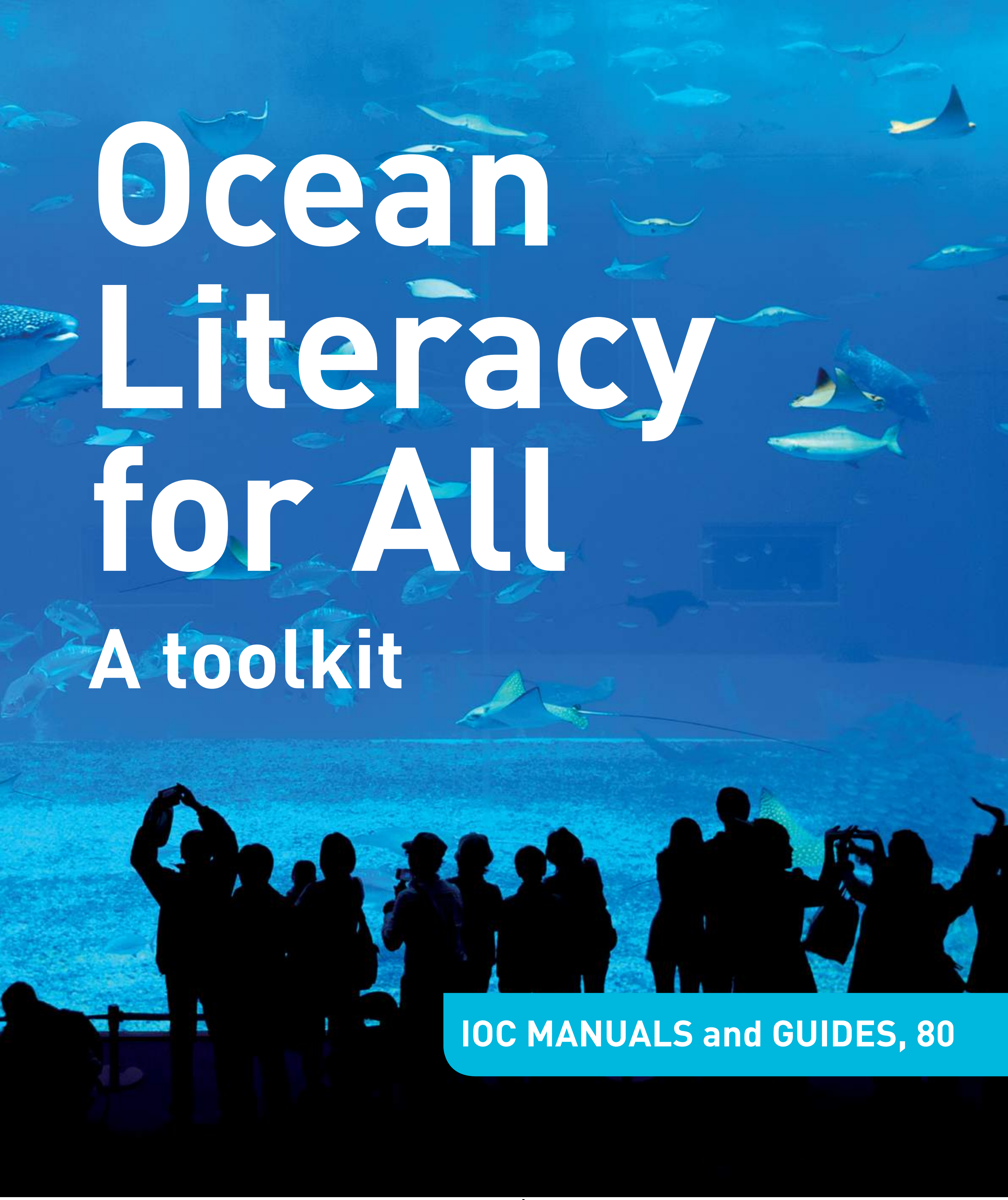

Ocean Literacy for All

A toolkit

IOC MANUALS and GUIDES, 80

United Nations
Educational, Scientific and
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Regional Bureau for Science and Culture in Europe

Intergovernmental Oceanographic Commission

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Foreword

The ocean is a source of food, energy, minerals, increasingly of medications; it regulates the Earth's climate and hosts the greatest diversity of life and ecosystems, and is a provider of economic, social and aesthetic services to humankind. Knowing and understanding the ocean's influence on us, and our influence on the ocean is crucial to living and acting sustainably. This is the essence of ocean literacy.

It is the result of increasing ocean literacy that the international community gathered in New York in June 2017 to discuss priority areas of action, set in motion joint activities, and develop partnerships to preserve the ocean. A global partnership, led by the Intergovernmental Oceanographic Commission (IOC) of UNESCO, was formed to raise the awareness on the conservation, restoration and sustainable use of the ocean and its resources and to build a public knowledge base regarding the global ocean.

The IOC-UNESCO Ocean Literacy for All A toolkit is the result of a joint work and contributions of members of this global partnership. It provides to educators and learners worldwide the innovative tools, methods, and resources to understand the complex ocean processes and functions and, as well, to alert them on the most urgent ocean issues. It also presents the essential scientific principles and information needed to understand the cause-effect relationship between individual and collective behavior and the impacts that threaten the ocean health.

We hope that this publication will inspire the readers - scientists, educators and learners - to take greater personal responsibility for the ocean, as well as to enable them to act as citizens, working through partnerships and networks, sharing ideas and experiences and developing new approaches and initiatives in support of ocean literacy.

The ocean is the great unifier and it is our shared responsibility to preserve it for the current and future generations.

We extend our warmest thanks to the Government of Sweden and to the Voluntary Commitment partners who contributed resources for developing the kit as part of their support for IOC-UNESCO.

Vladimir Ryabinin
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Executive Summary

Recognizing the lack of ocean-related subjects in formal education, a group of ocean scientists and education professionals in the US in 2002 initiated a collaborative and bottom-up process to develop a comprehensive framework to encourage the inclusion of ocean sciences into national and state standards, and for more teaching about the ocean in K-12 classrooms. This was the start of the ocean literacy movement that since then it has spread around the world through the development of marine science educators associations in Canada, Australia, Europe and Asia.

Ocean literacy programs and projects, until now, have been mainly focusing on developing resources, lesson plans and activities targeting Science, Technology, Engineering and Mathematics (STEM) education. Currently, and in particular after the adoption of the Sustainable Development Goal (SDG) 14, we have assisted to a shift in the focus towards the inclusion of approaches closer to those developed under the UNESCO framework of Education for Sustainable Development (ESD). ESD aims to improve access to quality education on sustainable development at all levels and in all social contexts, to transform society by reorienting education and help people develop knowledge, skills, values and behaviors needed for sustainable development. Individuals are encouraged to be responsible actors who resolve challenges, respect cultural diversity and contribute to creating a more sustainable world.

This publication is made of two parts. The first part presents the history of ocean literacy, and describes its framework made of 7 essential principles, and connects them to international ocean science programs that contributes to enhancing ocean knowledge and observations. Moreover, marine scientists and educators were interviewed to share their professional experiences on ocean literacy as well as their views on its future. The last chapter of part 1 describes the existing challenges to marine education, as well as the path for the development of successful ocean literacy activities in the context of the 2030 Agenda. One of the most important factors identified is related to the creation of multi-sector partnerships among the education, government, and private sector that have jointly built ocean literacy programs for all formal educational levels from the primary school to the university level as well as for non-formal learners. Worldwide examples of such programs are presented.

The second part, after introducing the methodological approach based on the multi-perspective framework for ESD developed by UNESCO, presents 14 activities that could provide tested examples and support for the implementation of marine education initiatives. The aim is not to provide a one size-fits-all ready to use collection, but rather to offer support and examples of what could be then adapted for different geographical and cultural contexts. The resources are designed to be relevant for all learners of all ages worldwide and to find their application in many learning settings, while in their concrete implementation they will, naturally, have to be adapted to the national or local context.

Ocean Literacy for All

A toolkit

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Part 1

Ocean Literacy for all – A toolkit

Part 1

1

Ocean Literacy: its history and its future

1

Ocean Literacy: its history and its future

1.1
The need for ocean literacy in a changing blue planet

1.2
Definition and history of ocean literacy

1.3
Building a global ocean movement: Connecting ocean science and education for sustainable development

1

Far and away, the greatest threat to the ocean, and thus to ourselves, is ignorance (Sylvia Earle, President of Mission Blue)

1.1 The need for ocean literacy in a changing blue planet

Most of us live our lives unaware of how our day-to-day actions affect the health and sustainability of the ocean and its many resources on which we depend. Nor do the majority of us recognize how the health of the ocean affects our daily lives. Most citizens are not aware of the full extent of the medical, economic, social, political, and environmental importance of the ocean and seas. However, what some scholars have called "ocean blindness" can be countered by improving access to accurate and compelling ocean education that strengthens the learner's connection with the ocean. This is the essence of ocean literacy: an understanding of the ocean's influence on us and our influence on the ocean.

The approval of a stand-alone United Nations Sustainable Development Goal (SDG) on the ocean, SDG14, has been a major achievement for the global ocean community. However, if we are to succeed in achieving SDG14 to "conserve and sustainably use the oceans, seas, and marine resources" and in implementing the necessary global ocean policies that will sustain healthy ocean ecosystems, we must build a global constituency for the ocean. Several national reports have been produced over the last decade that document the centrality of the ocean, coasts, and seas to the economy, environment and quality of life. They emphasize the need for increased ocean literacy to improve economic stability and national security, and to allow society to understand critical issues associated with important ocean-related topics spanning ecology, trade, energy exploration, climate change, biodiversity, the ocean and human health, and developing a sustainable future.


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One of the greatest challenges facing ocean education and public engagement is piercing the opacity of our global ocean. The public typically perceives the ocean as what they can see from the shore. Today's technology driven age is helping to mitigate this physical limit on ocean experiences and exploration. New open access data acquisition, data mining, and visualization tools present educators and communicators with opportunities to take the public with them into the depths of the sea. Fostering citizens' experiences, widening knowledge, and broadening perspectives around ocean science and sustainable development of the ocean and its resources are crucial to making regulatory policies more robust, effective, and trusted.

The need to conserve the ocean and sustain its resources is intimately linked with a pressing need for a well-trained ocean science (both natural and social), engineering, and technology workforce. This need is great, as the challenges to ocean ecosystems and the resources on which society depends worldwide are growing. In addition to impacts on coastal communities from sea level rise and coastal storms, other global ocean issues include increasing marine litter, marine biodiversity loss, destruction of fisheries across the globe, ocean acidification and deoxygenation. In 2017 UNESCO published the *Global Ocean Science Report—The current status of ocean science around the world* [1] which provides an overview of various nations' investments, resources, and scientific productivity in ocean science to tackle the aforementioned issues. Importantly, the report also addresses gaps in knowledge, research, capacity, and technical infrastructure across the globe, as well as opportunities for international collaboration.

Halting biodiversity loss, reducing marine litter, increasing the marine environment's protection, i.e., implementing SDG14, will require a shift in our lifestyles and a transformation of the way we think and act. To achieve this change, we need new skills, values, and attitudes that lead to more ocean-sustainable societies.

Education systems must respond to this pressing need by defining relevant learning objectives and content and by introducing ocean pedagogies that empower learners. Moreover, ocean literacy is more than just educating or informing the public and maritime stakeholders about the importance of the ocean. There is a need to engage with society and prepare people to do so. It is imperative that the global citizenry understands the societal impacts of ocean research and pressing ocean issues. Ocean literacy aims at facilitating the creation of an ocean-literate society able to make informed and responsible decisions on ocean resources and ocean sustainability.

1.2 Definition and history of ocean literacy

In the following section, the history of ocean literacy is presented as it started in the USA. It is important to underline that ocean literacy could have different meanings in different countries and culture. For example, Europe has many different basins, and regional seas with different cultural contexts and relationships to each other. Regional groups are being formed in Europe with the aim of adapting the original USA principles to each regional sea's specificity such as EMSEA Med, EMSEA Baltic and EMSEA North Sea and the English Channel. Each of them has its own cultural, geographical and societal particularity and this is being highlighted, for example; the Mediterranean group is underlining the importance of the Med Sea as the cradle of western civilization.

1

Recognizing the lack of ocean-related subjects in formal education, a group of ocean scientists and education professionals in the USA initiated a collaborative and bottom-up process to develop a comprehensive framework to encourage the inclusion of ocean sciences into national and state standards, and for more teaching about the ocean in K-12 classrooms. Early work to develop a consensus position on ocean sciences education began in 2002. The College of Exploration [2] and National Geographic Society (NGS) led an online conference in 2002, *Oceans for Life*, which paved the way for the development of the *Ocean Literacy Essential Principles and Fundamental Concepts* [3]. Moreover, two US national commissions, the Pew Commission in 2003 and the US Commission on Ocean Policy in 2004, stressed the need to expose students to ocean issues and enhance marine education and awareness to 'inspire the next generation of scientists, fishermen, farmers, business and political leaders' with a greater understanding and appreciation for the ocean [4]. It was then thanks to several US institutions and networks, such as the Center for Ocean Science Education Excellence (COSEE) [5], the National Marine Educators Association (NMEA) [6], the NGS, the National Oceanic and Atmospheric Administration (NOAA) [7], National Sea Grant College Program [8], Lawrence Hall of Science [9], the College of Exploration, the Ocean Project [10], and the Association of Zoos and Aquariums (AZA) [11] that the ocean literacy concept was further developed. In October 2004, the College of Exploration hosted a two-week online workshop, *Ocean Literacy Through Science Standards*, that involved approximately 100 people representing key constituencies for improving ocean literacy. These constituencies included: formal educators (primarily from K-12 schools but also colleges and universities); researchers from various sub-disciplines of ocean sciences; education policymakers; science coordinators from state and local departments of education; informal educators; and federal agency representatives involved in education and outreach. At the end of this online workshop, there was a consensus on the definition of ocean literacy, and on a set of principles, which were eventually narrowed down to the seven Essential Principles **(Table 1)** with 44 Fundamental Concepts. Through the review work of small teams of scientists and educators, the final document, *Ocean Literacy: The Essential Principles and Fundamental Concepts of Ocean Sciences* K-12 [12], was finalized. The document identifies the content knowledge that an ocean-literate person in the United States should know by the end of secondary school.

The essential principles of Ocean Literacy

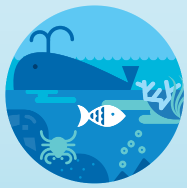
1. The Earth has one big ocean with many features

2. The ocean and life in the ocean shape the features of the Earth

3. The ocean is a major influence on weather and climate

4. The ocean makes the Earth habitable

5. The ocean supports a great diversity of life and ecosystems



6. The ocean and humans are inextricably interconnected

7. The ocean is largely unexplored

Table 1. The essential principles of ocean literacy

1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In 2006, the International Pacific Marine Educators Network (IPMEN) [13] was formed and the first conference was held in Honolulu, Hawaii in January 2007. Bi-annual conferences have been held since then. "Ocean Literacy" in its broadest sense was, and is, a foundational theme for these conferences. The design of the IPMEN conferences has emphasized the importance of local culture, traditional knowledge and trans-disciplinary experiences of the relationship between people, commerce, education and culture, with the ocean. The IPMEN vision is centered on the importance of global, national and local knowledge and exchange.

European ocean scientists and education professionals have also recognized the need to define a strategy to make ocean science a component of formal education curricula. One of the first European countries to implement an ocean literacy framework, both in formal and non-formal education, was Portugal. In 2011, under the leadership of Ciência Viva, the Portuguese National Agency for Scientific and Technological Culture, the *Ocean Literacy Essential Principles and Fundamental Concepts*, were translated into Portuguese. The *Conhecer o oceano* (Knowing the Sea) [14] project was developed to adapt the seven Essential Ocean Literacy Principles into the Portuguese context.

In 2011, at the annual NMEA conference in the US, several European marine scientists and educators proposed the creation of a sister association, the European Marine Science Educators Association (EMSEA) [15]. EMSEA is based on the vision that European marine educators need an effective transformation and stronger international connections in order to feel more supported, engaged, and equipped for the task to make European citizens more ocean literate [16], [17]. In 2012, the first Conference on Ocean Literacy in Europe was organized in Bruges. This one-day conference hosted high level speakers and leading experts in marine education who represented EU policy, national governments, international and intergovernmental organizations and European stakeholders.

The objectives of the conference were to address the lack of ocean-related content in science education standards and to envision how to bring ocean sciences into mainstream science education. Furthermore, the conference emphasized how formal and informal marine formal and non-formal education projects led to more public involvement and active participation. The conference, together with the organization of a 2013 workshop hosted by the European Marine Board (EMB) [18] and the Flanders Marine Institute (VLIZ) [19] defined recommendations to the European Commission DG Research and Innovation on mechanisms and initiatives to better support marine science outreach and education in the Horizon 2020 Programme [20]. This event was instrumental for the publication of one Horizon 2020 call on ocean literacy, which was issued to support the implementation of the Galway Statement on Atlantic Ocean cooperation between the EU, Canada and the US. In the Galway Statement, ocean literacy appears as follows:

We further intend to promote our citizens' understanding of the value of the Atlantic, by promoting ocean literacy. We intend to show how results of ocean science and observation address pressing issues facing our citizens, the environment and the world, to foster public understanding of the value of the Atlantic Ocean (EU-Canada-US. Research Alliance, 2013) [21].

In 2015, two Horizon 2020 projects, Sea Change Project [22] and ResponSEAble [23] started with the aim of making European citizens more ocean literate, and to support the implementation of the Galway Statement.

As the EU ocean literacy movement was gaining momentum, other national and regional associations related to marine science education were established, such as the Canadian Network for Ocean Education (CaNOE) [24], which is a network for the advancement of ocean literacy in Canada. CaNOE provides a platform for learning, dialogue, and communication about ocean literacy in Canada. By bringing educators and scientists together, the main objective is to create momentum that will increase regional and national understanding of the value of the ocean.

At the first Global Ocean Science Education (GOSE) Workshop [25] convened in 2015 by COSEE and the College of Exploration, a group of Asian educators started a discussion to create an Asian Marine Educators Association (AMEA). This discussion was continued by the Asian participants in the 2015 NMEA conference. A year later, a workshop was held at the Tokyo University of Marine Science and Technology (TUMSAT) [26] to define a framework for the association and to discuss goals and interest and membership.

While all these organizations and associations have been critical to promoting ocean literacy nationally and regionally, the need for international collaboration and exchange of good practices and experiences led to the engagement of UNESCO in ocean literacy, both through its Intergovernmental Oceanographic Commission (IOC) and its Education Sector.

This happened specifically through the organization of the GOSE Workshops, which are now conducted via a collaborative effort of the IOC, the College of Exploration, and COSEE. The 2016 and 2017 workshops were aimed at further strengthening the global ocean science education network by engaging the policy and the business sectors with the ocean research and education sectors. A key outcome of the 2016 workshop has been the establishment of five international working groups focused on workforce development to support the Blue Economy; common messages and communication tools; an online platform to share information on resources, people, and projects; resources and programs for policymakers and other stakeholders; and collaborations to support World Ocean Day.

1

History of Ocean Literacy

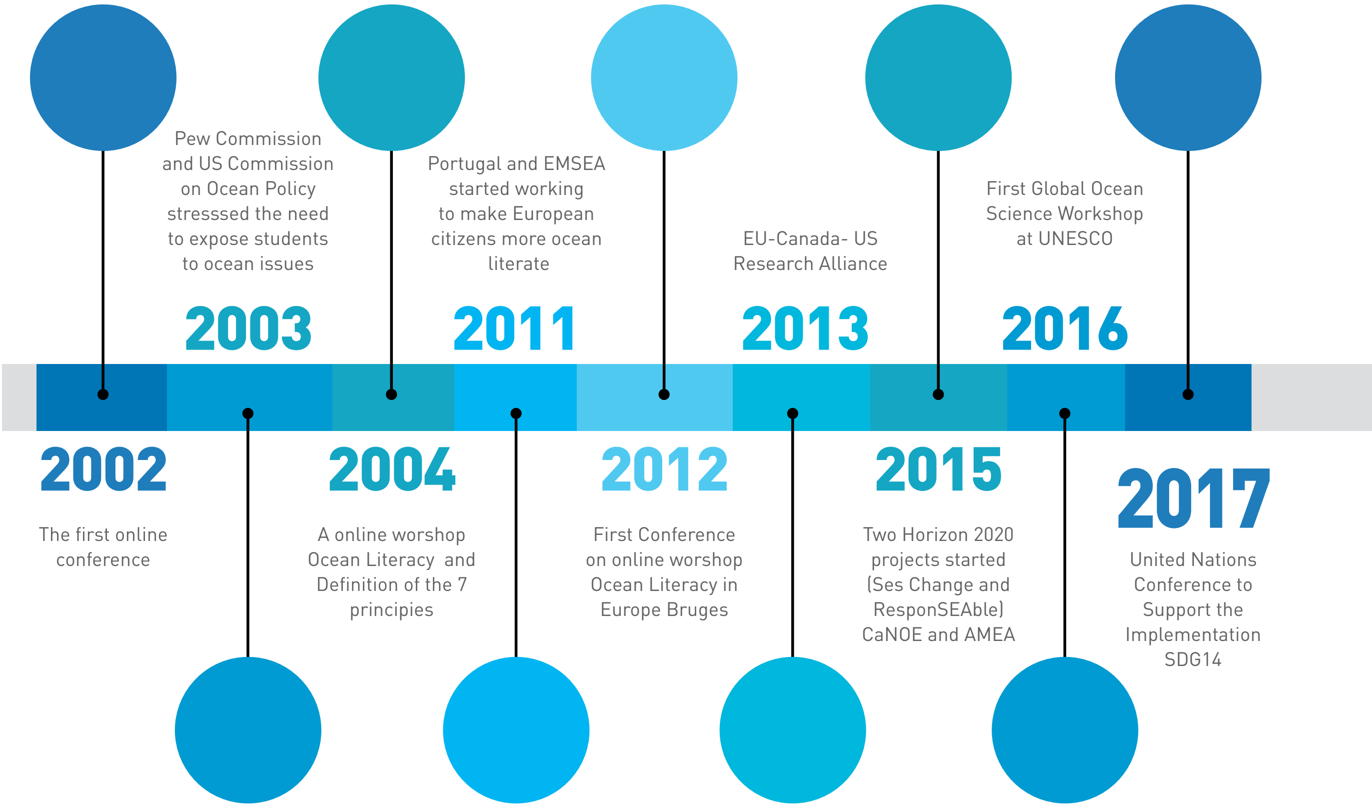


Figure 1. History of ocean literacy

The high-level United Nations Conference to Support the Implementation of Sustainable Development Goal 14: Conserve and Sustainably Use the Oceans, Seas and Marine Resources for Sustainable Development, convened at United Nations Headquarters in New York from 5 to 9 June 2017 and provided the platform to further promote the ocean literacy concept and framework internationally. A voluntary commitment, *Ocean Literacy for All: A Global Strategy to Raise the Awareness for the Conservation, Restoration, and Sustainable Use of Our Ocean*, was submitted by UNESCO in partnership with all the institutions mentioned above as well as with other relevant partners. The main aim of the initiatives outlined in the Voluntary Commitment is to develop a global partnership to promote improved public awareness across the world citizenry regarding our global ocean (**Figure 1**). A side event was organized during the UN Conference. The event was opened by the Director General of UNESCO, Irina Bokova, who stressed that:

"UNESCO, being the only UN agency with a mandate in education and ocean science is committed to promoting ocean literacy – individual and collective understanding of the importance of the ocean to humankind –, and to increasing awareness of the great value ocean research and ocean science provide to society. Bolstering ocean literacy at national, regional and local levels of leadership will foster States' capacities for adaptation, enhance the resilience of vulnerable communities, promote best practices in resource management and encourage innovative solutions for a sustainable blue economy."

Furthermore, the UN Ocean Conference adopted by consensus the intergovernmentally agreed declaration in the form of a "Call for Action", which declares that member states, in concert with relevant stakeholders agree to:

Support plans to foster ocean-related education, for example as part of education curricula, to promote ocean literacy and a culture of conservation, restoration and sustainable use of our ocean.

1.3 Building a global ocean movement: Connecting ocean science and education for sustainable development

The ocean literacy movement is growing rapidly across the globe, with more countries and institutions involved. Therefore, there is a need for tools, resources, and best practices to be shared and disseminated widely. This publication addresses these needs and aims at reaching the widest possible number of marine educators both in formal and non-formal contexts, to provide them with an introduction to the USA ocean literacy framework, as well as with lessons and activities that could provide tested examples and support for the implementation of their marine education initiatives. The aim is not to provide a one size-fits-all ready-to-use collection, but rather, to offer support and examples of what could be adapted for different geographical and cultural contexts. The resources are designed to be relevant for all learners of all ages worldwide and to find their application in many learning settings, while in their actual concrete implementation they will, naturally, have to be adapted to the national or local context.

Educators can use this text as a resource when developing training, textbooks, massive open online course (MOOCs), and exhibitions. It can help teachers or curriculum designers in formal educational institutions, trainers in professional capacity-building programs, or NGO staff designing non-formal educational offers. This publication should provide an introduction to ocean literacy, as well as deepen their understanding of its underlying concepts.

This publication also connects the work of the IOC, with a focus on its international ocean science programs, and UNESCO's experience in education for sustainable development. UNESCO aims, to improve access to quality education in sustainable development at all levels and in all social contexts, to transform society by reorienting education and to help people develop the knowledge, skills, values, and behaviors needed for sustainable development. Individuals are encouraged to be responsible actors who resolve challenges, respect cultural diversity, and contribute to creating a more sustainable world. A specific reference will be made to the Education for Sustainable Development Goals - Learning Objectives [27] and to its recommendations for SDG14 **(Table 2).**

SDG 14 LIFE BELOW WATER

Conserve and sustainably use the oceans, seas and marine resources for sustainable development

Learning objectives for SDG 14 "Life below Water"

Cognitive learning objectives	1. The learner understands basic marine ecology, ecosystems, predator-prey relationships. 2. The learner understands the connection of many people to the sea and the life it holds, including the sea's role as a provider of food, jobs and exciting opportunities. 3. The learner knows the basic premise of climate change and the role of the oceans in moderating our climate. 4. The learner understands threats to ocean systems such as pollution and overfishing and recognizes and can explain the relative fragility of many ocean ecosystems including coral reefs and hypoxic dead zones. 5. The learner knows about opportunities for the sustainable use of living marine resources.
Socio-emotional learning objectives	1. The learner is able to argue for sustainable fishing practices. 2. The learner is able to show people the impact humanity is having on the oceans (biomass loss, acidification, pollution, etc.) and the value of clean healthy oceans. 3. The learner is able to influence groups that engage in unsustainable production and consumption of ocean products. 4. The learner is able to reflect on their own dietary needs and question whether their dietary habits make sustainable use of limited resources of seafood. 5. The learner is able to empathize with people whose livelihoods are affected by changing fishing practices.
Behavioural learning objectives	1. The learner is able to research their country's dependence on the sea. 2. The learner is able to debate sustainable methods such as strict fishing quotas and moratoriums on species in danger of extinction. 3. The learner is able to identify, access and buy sustainably harvested marine life, e.g. ecolabel certified products. 4. The learner is able to contact their representatives to discuss overfishing as a threat to local livelihoods. 5. The learner is able to campaign for expanding no-fish zones and marine reserves and for their protection on a scientific basis.

Table 2. Learning objectives for SGD14 Life below Water [27]

References

[1]
UNESCO. 2017. *Global Ocean Science Report—The current status of ocean science around the world*, L. Valdés et al. (eds), UNESCO Publishing, Paris
http://unesdoc.unesco.org/images/0025/002504/250428e.pdf

[2]
College of Exploration http://www.coexploration.org/

[3]
Ocean Literacy Essential Principles and Fundamental Concepts
http://oceanliteracy.wp2.coexploration.org/long_history/

[4]
Paul, L. M. B. 2004. *The 2003 Pew Oceans Commission Report: Law, Policy, and Governance*. Natural Resources & Environment. Vol 19, No 1
http://www.jstor.org/stable/40925134)`

[5]
COSEE Consortium for Ocean Science Exploration and Engagement.
http://www.cosee.net/

[6]
National Marine Educators Association
http://www.marine-ed.org/

[7]
NOAA National Oceanic and Atmospheric Administration
http://www.noaa.gov/

[8]
National Sea Grant College Program
http://seagrant.noaa.gov/

[9]
Lawrence Hall of Science
https://www.lawrencehallofscience.org/

[10]
The Ocean Project
http://theoceanproject.org/

[11]
Association of Zoos and Aquariums
https://www.aza.org/

[12]
Ocean Literacy: The Essential Principles and Fundamental Concepts of Ocean Sciences K-12
http://oceanliteracy.wp2.coexploration.org/ocean-literacy-framework/

[13]
International Pacific Marine Educators Network IPMEN
http://ipmen.net/

[14]
Conhecer o oceano
http://www.cienciaviva.pt/oceano/home/

[15]
European Marine Science Educators Association, EMSEA
http://www.emsea.eu/

[16]
Copejans E, Crouch F, Fauville G. 2012. The European marine science educators association (EMSEA): Towards a more ocean literate Europe. *The Journal of Marine Education* 28: 43-46.

[17]
Fauville G, Copejans E, Crouch F. 2013. European marine educators, unite! Europe's quest for a more ocean-oriented society and economy. *The Marine Biologist* 1: 30-31.

[18]
European Marine Board
http://www.marineboard.eu/

[19]
VLIZ Flanders Marine Institute
http://www.vliz.be/en/node/16

[20]
Horizon 2020 Programme
https://ec.europa.eu/programmes/horizon2020/

[21]
EU-Canada-US. Research Alliance, 2013
https://goo.gl/iXpe6N

[22]
Sea Change Project
www.seachangeproject.eu

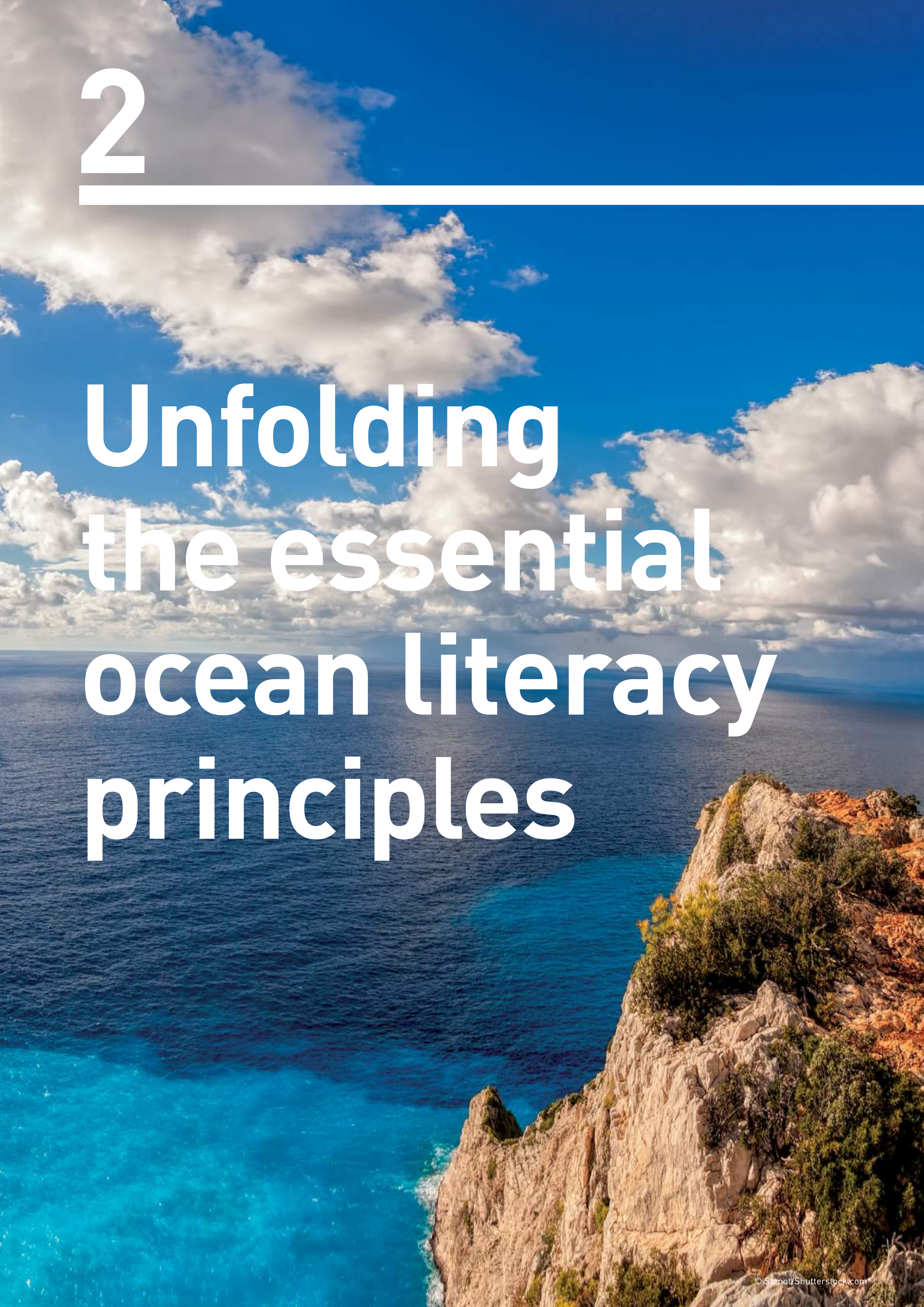
[23]
ResponSEAble
http://www.responseable.eu/

[24]
Canadian Network for Ocean Education
http://oceanliteracy.ca/

[25]
Global Ocean Science Education Workshop
https://goo.gl/8aKTig

[26]
Tokyo University of Marine Science and Technology
https://www.kaiyodai.ac.jp/english/

[27]
UNESCO.2017. *Education for Sustainable Development Goals - Learning Objectives,* UNESCO, Paris.
http://unesdoc.unesco.org/images/0024/002474/247444e.pdf



2

Unfolding the essential ocean literacy principles

2

Unfolding the essential ocean literacy principles

Overview

Principle 1 **The Earth has one big ocean with many features**

Principle 2 **The ocean and life in the ocean shape he features of the Earth**

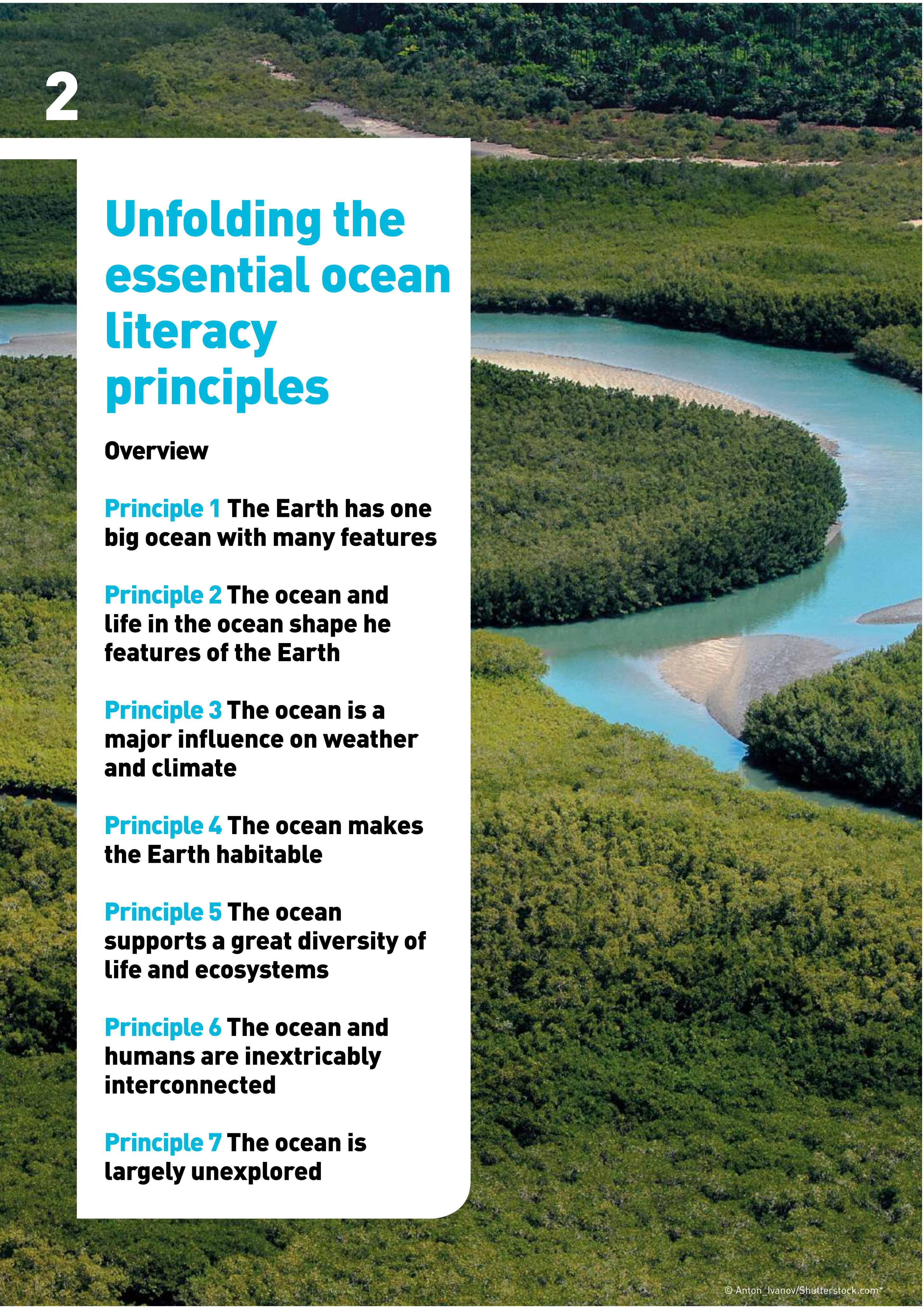
Principle 3 **The ocean is a major influence on weather and climate**

Principle 4 **The ocean makes the Earth habitable**

Principle 5 **The ocean supports a great diversity of life and ecosystems**

Principle 6 **The ocean and humans are inextricably interconnected**

Principle 7 **The ocean is largely unexplored**



2

My ocean is your ocean, my ocean is our ocean (Karmenu Vella, European Commissioner for Environment, Maritime Affairs and Fisheries)

Overview

In this chapter, all the essential principles will be presented and described as they were developed and defined by the American review work by scientists and educators in the final document Ocean Literacy: *The Essential Principles and Fundamental Concepts of Ocean Sciences* K-12.

Each principle is unfolded with examples, researchers' studies, historical data and cultural information referring to the principle's context. This strengthens and solidifies the relationship between the specifics of each principle and the necessary scientific approach and the citation of international research programs also serves to demonstrate the deeper, scientific, context for the principles.

In addition, interviews with experts, educators, and scientists working and studying all over the world aim to enhance a multidisciplinary approach and to add a personal note on the path of the implementation of the ocean literacy principles with respect to the different cultural, historical, geographical, economic and societal point of view.

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2

Principle 1 The Earth has one big ocean with many features

In 1992, a shipping container filled with 28,000 yellow rubber ducks was lost at sea, having fallen overboard on the way from Hong Kong to the USA. Since that day, ducks have bobbed halfway around the world and have washed up on the shores of Hawaii, Alaska, South America, Australia, and the Pacific Northwest. Others have been found frozen in Arctic ice. The toys spent over a decade circling the ocean until at least the mid-2000s. In 2012, a group of oceanographers from the University of New South Wales confirmed with 20000 satellite-tracked drifter buoys that the floating objects took a much longer journey than previously realized. They discovered that these plastic toys, as well as other objects, can migrate between ocean water masses over long timescales, and these water masses are more connected than ever envisioned. Though the five ocean basins (Atlantic, Pacific, Arctic, Southern, and Indian) can be considered as separate bodies, they are interconnected as one global ocean. This can be easily seen in looking at a map of the world from the South Pole. The connections among the ocean basins allow seawater, matter, and organisms to move from one basin to another.

Throughout the global ocean, there is one interconnected circulation system that is powered by winds, tides, the force of the Earth's rotation, the Sun, and water density differences. This circulation system creates a moving conveyor belt of linked surface and deep water currents. This global ocean conveyor belt moves water throughout the ocean basins, transporting heat and energy around the world and thus serving as a key ingredient in the planet's climate system. Water systems dominate planet Earth, approximately 71% of the Earth's surface is covered by water. About 96.5% of this water is contained in the global ocean. The remainder of the Earth's water exists in atmospheric water vapor, rivers and lakes, ice, soil, aquifers, and many forms of life.

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Seawater has unique properties. It is salty due to the natural erosion process of slightly acidic rain interacting with rock. Rain causes erosion, leading to the creation of ions that are carried by rivers and streams and eventually reach the ocean. These dissolved ions have built up in the ocean over time, increasing the ocean's salinity. The six major dissolved ions in seawater are sodium, chloride, magnesium, sulfate, calcium, and potassium. Seawater freezes at a slightly lower temperature than fresh water. It is also denser and has more electrical conductivity.

The ocean plays an important part in the Earth's water cycle, which circulates water from the atmosphere, ocean, rivers, and lakes across the planet. The Earth's water cycle is in constant motion due to physical and chemical drivers. The travel of water masses within the ocean is powered by these drivers. The main physical driver is the heat of the sun, which causes evaporation, leading to cloud formation and then ultimately rain.

Another important property of the ocean is the rise and fall of its height across the globe, over time, due to Earth's geological processes and, daily, with the tides. Sea level is the average height of the ocean relative to the land. Sea levels may change over long periods of time as the movement of tectonic plates may cause changes in water volume capacity of the ocean basins as well as in the height of the land. The sea level also alters as land-based ice melts or grows in volume. It can also change as seawater expands and contracts when the ocean warms and cools.

Although the ocean is large, it is finite, and its resources are limited.

2

Ocean Science for Ocean Literacy

JCOMM

The Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM) is an intergovernmental body of technical experts that provides a mechanism for international coordination of oceanographic and marine meteorology, which observes data management and services and combines the expertise, technologies, and capacity-building abilities of the meteorological and oceanographic communities. The creation of this Joint Technical Commission results from a general recognition that worldwide improvements in coordination and efficiency may be achieved by combining the expertise and technological capabilities of the World Meteorological Organization (WMO) and UNESCO's Intergovernmental Oceanographic Commission (IOC). The JCOMM also provides access to ocean data, including data related to ocean temperature, salinity, and currents.

IODE

The program International Oceanographic Data and Information Exchange (IODE) of the Intergovernmental Oceanographic Commission (IOC) of UNESCO was established in 1961. Its purpose is to enhance marine research, exploitation, and development, by facilitating the exchange of oceanographic data and information between participating Member States, and by meeting the needs of users for data and information products. During the past 50 years, IOC Member States have established more than 80 oceanographic data centers in as many countries. This network has been able to collect, control the quality of, and archive millions of observations of the global ocean, and makes these available to all Member States.

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2

Danilo Calazans
Universidade Federal do Rio Grande (Brazil)

Why is ocean education/OL important to you?

Ocean literacy is important to me because it sees me bring maritime awareness to children who are early in their educational learning. I think it is extremely important to bring them knowledge about the importance of human beings' impact and that of their current and future actions. Those actions can and should be developed to improve the health of the ocean. It is through these young students that it will be possible to bring a maritime conscience to older people who had no opportunity to be educated to have such an awareness, an awareness that is so important these days.

Which/When was your best OL/Ocean Science education experience?

A boarding experience

The active participation of students from Oceanography courses on research cruises in Brazil was usually restricted, since the few extra spaces available were occupied by researchers, technicians and scholarship students directly involved with the work to be performed. The requirement of an on-boarding experience for the completion of Oceanography courses was introduced in 1989. Since then, among other requirements, students must complete 120 hours on board. In 1996, the Oceanology Course Commission of Federal University of Rio Grande - FURG created a discipline: "Oceanographic Techniques and Equipment Practices," with the objective of "preparing the students to get experience on oceanographic data collection, analysis and how to observe abiotic and biotic aspects during a cruise aboard a research vessel that would serve as an advanced oceanography laboratory." Before boarding, a lecture is given to show the importance of properly collecting the data and before navigation began, they are given information about safety and behavior on board. During the cruise, they are shown how to use and handle various instruments and equipment to collect abiotic data and distinct groups of marine organisms. The students facilitate the interactions of abiotic parameters and biotic data; observations on hydro acoustic prospecting; they learn to make morphological and sedimentological maps; characterize and determine masses of water; evaluate the water quality of the region; learn the basics of navigation and how to locate a vessel in the ocean and become familiar with rescue procedures at sea. I participate actively in a Ministerial commission to find ways to promote student's participation in oceanographic cruises. Four new vessels are being built by the Ministry of Education. They are the Floating Teaching Laboratories, which will on-board students from all over Brazil.

What do you think are the future should look like for OL?

We must be aware that we know only 5% of our entire ocean, which covers more than 70% of the planet. We must greatly improve the teaching of undergraduate students in Ocean Science courses and at the same time work with more emphasis on a way to bring teaching the importance of the Ocean to the younger ones by showing them that the ocean is the most important equilibrium environment of our planet. The ocean, from my point of view, is more important as a balancing actor than a food producer for us.

2

Principle 2
The ocean, and life in the ocean, shape the features of Earth

The cliffs of Normandy have always fascinated sailors and travelers. These cliffs have inspired famous painters, such as Claude Monet, and attracted many visitors. Vertical white walls stand on the blue horizontal skyline. The cliffs' geographical position is a reference for every traveler, both from sea and land.

The cliffs of Normandy are an example of a coastal landform, which were shaped, in part, by the action of the ocean and formed over geological time. There are many factors that caused the formation. The slow, continuous movement of seawater, erosion of land, and deposition of the ocean sediments across geological eras worked together to create this special landscape. Sea level changes, wave and tidal action, and tectonic activities also influence the many possible formations of the world's coastal areas, including the geological structure of hills and mountains that can be observed and visited today.

A stunning example of the ocean's influence on land formations is the Italian Dolomite Mountain Range, known as the Italian Dolomites. This beautiful region was added to the UNESCO World Heritage Site list in 2009. It features some of the most beautiful mountain landscapes on Earth, with vertical walls, sheer cliffs, and a high density of narrow, deep, and long valleys. The Italian Dolomites were literally born out of the sea. In the 19th century, scientists discovered that the sandstone and tuff deposits, surrounding the mountain's peaks of dolostone, contained large limestone boulders, some containing still recognizable fossils of corals. The scientists theorized that the mountain peaks were made from remains of an ancient coral reef, still surrounded by marine sediments of an ancient ocean basin. Modern research has furthered this work and determined that the geology of the Dolomites is very complex. The mountains provide a historical record of

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an early tropical sea, the Tethys Sea. It is now possible to walk over the ancient lagoons and margins of this sea while trekking in the Dolomites, where marine life once thrived on the banks of the Tethys. A thousand meters below the tops of the Dolomites, was the sea bottom, rich with marine life.

The geologic record of the Tethys Sea, contained in the beauty of the Italian Dolomites, has helped scientists understand the influence of this early sea on the land. A slow sinking of the land gradually allowed the sea to invade the entire region, which then became a warm and shallow expanse of water. For over approximately 8 million years, starting from the Triassic (over 251 million years ago), the depth of the Tethys Sea changed cyclically, sometimes leading to the temporary emergence of land, followed by other phases when the water was deeper. These cycles created the landscape that can be seen today.

The cliffs of Normandy and the Italian Dolomites are just two examples of how the ocean and the life it contains shape the land. Similar examples can be found on every continent, and today's ocean is continuing its architectural processes. Not all ocean influences occur over geological eras. With current global sea level rise, relatively rapid changes can be seen occurring on small island states and in coastal communities across the globe.

2

Ocean Science for Ocean Literacy

GLOSS

The Global Sea Level Observing System (GLOSS) is an international program conducted under the auspices of the Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM), the World Meteorological Organization (WMO) and the Intergovernmental Oceanographic Commission (IOC). GLOSS aims at the establishment of high quality global and regional sea level networks for application to climate, oceanographic and coastal sea level research. The program became known as GLOSS as it provides data for deriving the "Global Level of the Sea Surface". The main component of GLOSS is the Global Core Network (GCN) of 290 sea level stations around the world for long term climate change and oceanographic sea level monitoringmakes these available to all Member States.

Luis Pinheiro
Universidade de Aveiro (Portugal)

Ocean Education and the promotion of Ocean Literacy are fundamental for general public awareness, appreciation and understanding of the critic al and global importance of the oceans in sustaining all forms of life on Earth, which includes, of course, mankind. Fundamental too, is the need to appreciate their vastness, beauty and mysteries, extremely rich biodiversity, important resources and the major role they play in atmosphere and climate regulation, critical for our sustainable development and for that of future generations.

Ocean Education/Literacy are also essential for the general awareness of the growing threats that the oceans have been facing from negative human impacts such a pollution, acidification, eutrophication and resource overexploitation, amongst others, which require urgent action at international and intergovernmental level. The ocean forms a single entity, uniting us all and providing major communications and transportation highways, but they easily convert any local/regional negative impacts into global threats, through ocean circulation and ocean-atmosphere interaction. Only through Ocean Education/Literacy and the translation of the best available science into simple but accurate language for the non-specialists, reaching all stakeholders and decision makers, will it be possible to create an educated society capable of making informed decisions, and one that cares for the preservation of the health of the oceans, which ultimately impacts on our own health and the sustainable use of the vast ocean resources while preserving ecosystems.

Why is ocean education/OL important to you?

Which/When was your best OL/Ocean Science education experience?

Ocean Literacy/Ocean Science Education can be promoted and carried out in many highly valuable and complementary forms, from conferences and exhibitions targeted at specific audiences to films, brochures and all kinds of educational/civic activities. Nevertheless, as a marine scientist, I firmly believe that one of the best ways to motivate the general public and in particular the younger audiences for Ocean Science and the Oceans in general, is to take them to the sea. Since participation on a research cruise is not easy, the promotion of short cruises on small vessels in estuaries/lagoons or close to shore, devoted to science outreach, allows the general public, with a wide age span and with different backgrounds, to have a brief but direct experience of what marine multidisciplinary integrated research is, interact with a team of scientists from different disciplines and get to know some of the equipment used for sampling and for carrying out direct and remote-sensing marine investigation. I have been promoting such short cruises for students and for the general public for many years, with support from many entities, and it has always been a highly rewarding experience. One of my most striking and unforgettable experiences, however, was the participation in Training Through Research Cruises, between 1999 and 2008, carried out within the scope of the Floating University Program, conducted by the unfortunately deceased Prof. Michael Ivanov from Moscow State University, with the support of the IOC. The concept of experienced researchers training, through such a program, hundreds of students and young scientists from a large number of countries in multidisciplinary marine research at sea, while actually doing it, investigating cutting edge scientific targets, is, in my view one of the best ways to proceed and it was an unforgettable and highly rewarding human and scientific experience. Many, if not most, of the young students/researchers are now well known and highly qualified scientists all over the world.

Which/When was your best OL/Ocean Science education experience?

I am highly confident that the Ocean Literacy and Ocean Education can play a major role in changing societal views towards the oceans, their protection, health and sustainable use of their resources. Allowing informed decisions to be made on the basis of the best available science, is becoming more and more recognized as fundamental. A joint vision and action at international and intergovernmental level is required, and the IOC, as the UN joint specialized mechanism for ocean science and services, plays a major role in this process; in making recommendations and coordinating programs in education, training and assistance in marine science. The recent adoption by the 29th IOC Assembly of an International Decade of Ocean Science for Sustainable Development 2021-2030 – "Towards the ocean we need for the future we want" should hopefully, under the auspices of the United Nations, will be a major step towards promote international cooperation in ocean science and will play a key role in promoting Ocean Education and Ocean Literacy.

2

Principle 3

The ocean is a major influence on climate and weather

People experience the influence of the ocean on weather and climate at all times and often in dramatic events, such as tropical cyclones, typhoons and hurricanes. In the 1600s, fishermen off the coast of South America named a phenomenon of unusually warm water that they experienced off their Pacific Ocean coast the El Niño. They named it this because these events would occur close to Christmas time. El Niño means The Little Boy or Christ Child in Spanish.

The scientific term El Niño Southern Oscillation (ENSO) Event refers to a large-scale ocean-atmosphere interaction in the tropical Pacific that results in a somewhat periodic variation between below normal and above normal sea surface temperatures and dry and wet conditions over the course of a few years. Though ENSO is a single climate phenomenon, it has three potential phases: El Niño, La Niña, and Neutral. A phase of below normal sea surface temperatures is called La Niña, and Neutral is in the middle of the continuum. El Niño and La Niña phases require certain changes in both the ocean and the atmosphere because ENSO is a coupled climatic phenomenon.

The ENSO events can have a significant impact on people. During times of El Niño, waters in the central to eastern tropical Pacific are warmer than usual, causing habitat disruptions for marine life. Subsistence fisheries can crash, causing devastating economic impacts to coastal communities in South America. During a strong ENSO event, which may last for more than one year, the west coasts of North and South America will experience increased rain. Over Indonesia, rainfall will tend to reduce, while rainfall increases over the tropical Pacific Ocean. People in India depend on the summer monsoon winds to bring

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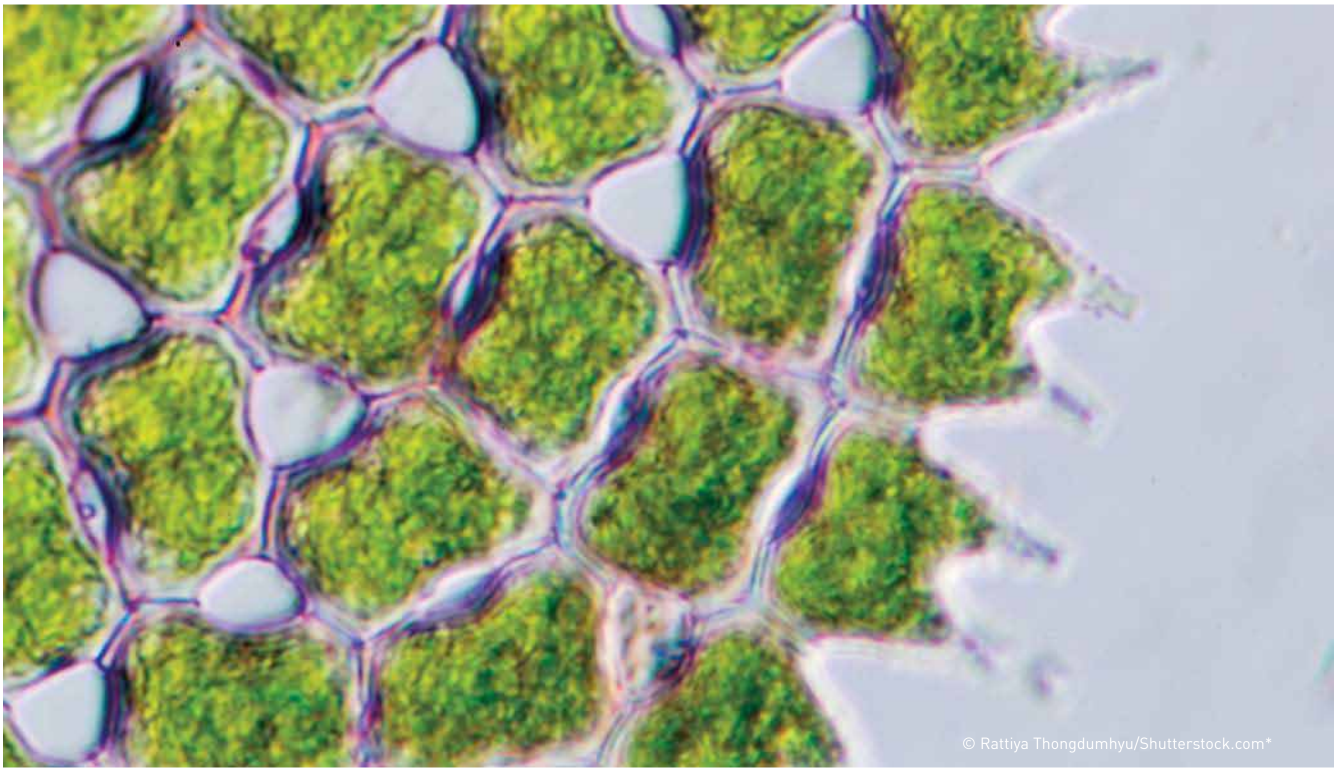

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rain for their crops. During El Niño, the monsoons can fail, producing famine and hardship. The Southern Oscillation refers to a long-distance linkage in atmospheric (or barometric) pressure and the ocean. When the pressure is high over the Pacific Ocean, it tends to be low over the Indian Ocean, and vice versa.

There are many other examples of the influence of the ocean on weather and climate. In a global sense, the ocean continually exchanges carbon dioxide, an important greenhouse gas, with the atmosphere. However, more carbon dioxide is stored each year than is released from the ocean, with the ocean serving as a major "sink" for carbon dioxide. Carbon dioxide in the Earth's atmosphere keeps the planet from freezing. With increasing levels of carbon dioxide in the atmosphere due to the burning of fossil fuels and other human activities, the planet is warming. The ocean is playing an important role in taking some of this "extra" greenhouse gas out of the atmosphere. Marine life, such as phytoplankton and algae, remove carbon dioxide from the atmosphere during respiration. Plankton use the carbon dioxide to build their skeletons. When they die, their skeletons sink to the ocean floor, causing the carbon dioxide they used while alive to become stored in ocean sediments.

Ocean currents allow the ocean to absorb, store, and transfer heat. These abilities allow the ocean to have a major influence on climate. Most rain that falls on land originally evaporated from the ocean. As water evaporates from the ocean it transforms into water vapor that is incorporated into the atmosphere. Some of this water vapor rises and helps to form the clouds from which rain falls.

The ocean is a key element of the global climate system, but for many years, ocean processes had been relatively absent from discussions on climate change. More recently, beginning with the United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties 21 in 2015, the climate change negotiations included the ocean. At its 43rd Session (Nairobi, Kenya, 11 – 13 April 2016), the Intergovernmental Panel on Climate Change (IPCC) decided to prepare a special report on climate change, the ocean, and the cryosphere. It will be released in 2019.

2

Ocean Science for Ocean Literacy

WCRP

The World Climate Research Programme (WCRP) facilitates analysis and prediction of Earth system change for use in a range of practical applications of direct relevance, benefit, and value to society. WCRP aims to determine the predictability of climate and the effect of human activities on that climate. A main WCRP research focus is observing changes in the components of the Earth system (atmosphere, oceans, land and cryosphere) and in the interfaces between these components. They are conducting important research that is increasing our understanding of the ocean's influence on weather and climate.

IPCC

The Intergovernmental Panel on Climate Change (IPCC) is the leading international body for the assessment and forecasting of climate change. The IPCC was established by the United Nations Environment Program (UNEP) and the World Meteorological Organization (WMO) in 1988 to provide a clear scientific view of the current state of knowledge about climate change and its potential environmental and socio-economic impacts. In the same year, the UN General Assembly endorsed the action by WMO and UNEP by jointly establishing the IPCC.

Tosca Ballerini
Expédition MED (France)

Why is ocean education/OL important to you?

The ocean is part of collective goods. Having a healthy ocean is important to me both on spiritual and practical terms: as a scuba diver and sailor, I love the ocean and love the organisms that live in it; as a marine biologist, I recognize the ecosystem service (natural resources, role in climate regulation, etc.) it provides for human life on Earth.

Ocean education and OL are important to me because I would like more people to get to know and appreciate the goods and services the ocean provides us. I think that if people knew the ocean better, they would be more interested in protecting it.

Ultimately, ocean education and OL are important to me because I want to protect the ocean and I would like people to join me in this effort.

Which/When was your best OL/Ocean Science education experience?

My best Ocean Science education experience was during the scientific survey Expédition MED 2017, which was dedicated to the study of plastic pollution in the Mediterranean Sea in the framework of a citizen science project.

I was the scientific officer of the expedition and had the chance and opportunity to coordinate the work of fellow researchers but also the work of volunteer citizens that participated in the sampling phases of plastic fragments at sea. Volunteers had the chance to learn how a scientific investigation is built (choosing the sampling sites, performing the sampling, recording metadata to be used in later phases of the analysis) and they had the chance to become autonomous in the sampling activities.

Some volunteers were very implicated in the fieldwork and provided feedback on the sampling procedures and protocols. Crucially, they saw how science research is done and thus realized that some parts of the scientific process can be learned by everyone.

What do you think are the future should look like for OL?

I think citizen science laboratories are an excellent way to develop OL. First-hand experience can teach much more than words, especially for people who have not had previous occasions to learn about the ocean and the services it provides.

I think it is important to stress the role played by the ocean in climate regulation.

I think OL has to include the concept that the ocean is part of common goods, such as clean air and stable climate. If people understand that the ocean is also THEIR ocean, I hope they will be willing to protect it.

One condition necessary to want to protect something is to know and to love it. So I think that learning about the wonders of marine life, or the beauty of the sunrise or sunset over the ocean is important.

I think that different approaches have to be used to bring people close to the ocean: books, documentaries, hands-on experiences with outreach and education (cleaning a beach from marine litter, but also sleeping at night on a beach to look at the sunset and the sun rise; participating in at-field surveys such as in the case of Expéditon MED).

2

Principle 4
The ocean made the Earth habitable

Scientists have theorized that life on Earth most likely originated in the sea. Therefore, the study of marine organisms can teach us about the history of life on earth. Some of the research on the origin of life has been conducted by looking for life in extreme environments, where life thrives without relying on the sun as an energy source. This is because the first life forms, microbial in nature, are thought to have evolved when Earth's atmosphere was blanketed by thick gases that blocked out much of the sun's influence. By understanding how life can live without the sun, it can be possible to discover how life began on Earth and whether Earth is the only place in the universe capable of supporting a biosphere.

Oceanographic research expeditions to study microbial life in extreme environments have helped to develop credible theories on the origin of life. Vast numbers of marine microbes live in the seafloor. The earliest evidence of life found thus far has been found in marine deposits.

In March 2017, researchers from the University College of London reported evidence of possibly the oldest forms of life on Earth. In slices of rock recovered from northern Quebec, structures were found embedded in iron crystals that appear to be fossils formed around hydrothermal vents. These structures are similar to those produced by microbes living around undersea hydrothermal vents.

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They grow as filaments, produced as microorganisms feed on iron compounds and create tube-shaped cavities in the sediment. The microorganisms may have lived as early as 4.28 billion years ago, not long after the oceans formed (4.4 billion years ago) and not long after the formation of the Earth. However, some scientists doubt that they are the remains of microbes. Others note that the age of the crystals cradling the potential microfossils is controversial, and the structures may be more than a billion years younger than reported. So, more research is needed to verify the age of the fossils.

The ocean is not only where life is thought to originate but it has also generated much of the oxygen that is required by many of Earth's organisms. Phytoplankton living in the ocean's surface waters produce oxygen through photosynthesis. Some of this oxygen is released to the atmosphere. Over the course of geologic time, enough oxygen was emitted by the ocean to allow oxygen breathing life forms to evolve. The ocean continues to provide water, oxygen, and nutrients and moderates the climate needed for life to exist on Earth.

2

Ocean Science for Ocean Literacy

GOOS

A better understanding of ocean climate and ecosystems, as well as human impacts and vulnerabilities, requires the coordination of a continuous and long-term system of ocean observations. In this context, the Global Ocean Observing System (GOOS) coordinates observations around the global ocean for three critical themes: climate, ocean health, and real-time services. These themes correspond to the GOOS mandate to contribute to the UNFCCC Convention on climate change, the UN convention on biodiversity and the IOC/WMO mandates to provide operational ocean services, respectively. Three discipline-based GOOS Expert Panels provide scientific oversight on Physics, Biogeochemistry, and Biology and Ecosystems. Of the three panels, the Physics and Biogeochemistry Panels were built on existing structures - the Physics Panel on the Ocean Observations Panel for Climate (OOPC) and the Biogeochemistry Panel on the International Ocean Carbon Coordination Project (IOCCP). The Biology and Ecosystems Panel was formed more recently and draws on the experience from the last decade of research best practices in this field. Expert Panels are central in the GOOS work structure, as they focus on the dispersed GOOS Networked observations, acting as a liaison and advocate for users and collaborators at local, national, and regional scales.

Pascale Chabanet
Institute of Research for Development and Western Indian Ocean Marine Science Association (France)

Why is ocean education/OL important to you?

As science develops new knowledge on natural environments and proposes tools to ensure better management of the environment, the appropriation of this knowledge by society and their translation in the form of actions and policies public is far from systematic.

It is why it is important today to take action by promoting the links between science and society, and between science and policy makers. The reinforcement of these links can be done with Ocean literacy by increasing the awareness of the citizens, from a young age.

Ocean literacy is a decisive lever of change for ocean management; facilitating the transfer of scientific knowledge to communities, managers and multi-level decision-makers with the goal to transform science to action and reinforce the political action.

Which/When was your best OL/Ocean Science education experience?

My best experience was given to me by feedback from the use of an educational toolbox on coral reefs (MARECO, the coral reef in our hands) that I developed with other scientists, our goal was to disseminate research results on coral reefs. An interdisciplinary research program conducted since 2014, used MARECO as a tool to study children's perceptions and representations of coral reefs through drawings and to assess the impact of the environmental awareness campaign before and after using the toolbox.

This program involved an interdisciplinary research team (natural and social sciences), teachers and schoolchildren. What has particularly touched me is to see how each teacher has appropriated and adapted the toolbox, using their own creativity to transfer the messages resulting from science. These links between science-society interface have been made successful by involving teachers as actors in the transfer of science to children, and this in different environmental (urban, rural and coastal) and cultural contexts (French overseas territories, Madagascar). As for the children, they not only absorbed the knowledge given by the teachers but were also actors by proposing solutions to better manage a marine ecosystem such as coral reefs.

What do you think are the future should look like for OL?

It is essential today to accentuate the decompartmentalization between science and society, the construction of sustainable ocean management being collective action. This decompartmentalization has to be done also between science and policy by pushing forward science in the heart of policy decisions to manage the oceans.

Ocean literacy has an essential role to play in this new direction, by facilitating the knowledge transfer from science to society and make people more involved in the decision-making process. We have to be creative for that and innovate tools that facilitate these links. Share success stories with managers and policy makers through publications adapted to the target audience, communicate experiences and scientific results both at local (village) and regional/international scales during political decision-making (COP, UN organizations). The science-policy link is a long-term perspective in which a society's awareness of environmental risks and challenges is a major lever for political action.

2

Principle 5
The Ocean supports a great diversity of life and ecosystems

Ocean ecosystems are numerous and diverse. They include the abyssal plain, polar regions, coral reefs, the deep ocean, mangroves, kelp forests, salt marshes, and sandy shores, among others. Ocean ecosystems are defined by environmental factors and by the community of organisms living there. Ocean life is not evenly distributed through time or space due to differences in abiotic factors such as available oxygen and nutrients, salinity, temperature, pH, light, pressure, substrate, and circulation. Other factors can cause vertical life zones both along coasts and in the open ocean. These factors include water density and pressure, light levels, tidal and wave action and predation. Zonation patterns can influence organisms' distribution and diversity.

Marine biodiversity refers to the variety of living organisms in the ocean; microbes, invertebrates, fishes, marine mammals, plants and birds. These biota are intricately connected with the environmental conditions in which they occur and also with each other through the flow of energy (food) through the ecosystem. Any changes in the environment or this energy flow will lead to changes in biodiversity.

Some ocean regions are considered biodiversity hot spots because of the wealth of species living there. For example, estuaries provide important and productive nursery areas for many marine species.

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The oldest life on Earth is believed to have evolved in the ocean. The longest-living vertebrate discovered thus far has been found in the ocean. A recent research study by Julius Nielsen and collaborators describes how the researchers determined, with radiocarbon dating, the ages of 28 Greenland sharks, one being a female approximately 400 years old. The largest invertebrate on Earth is found in the ocean, the mysterious giant squid. The largest of these elusive giants ever found measured 18 meters in length and weighed 900 kilograms. These are just examples of the great biodiversity that can be found in the ocean, from the smallest living organisms to the largest animal currently alive, the blue whale. Most of the major groups that exist on Earth are found exclusively in the ocean and the diversity of major groups of organisms is much greater in the ocean than on land. Ocean biology provides many unique examples of life cycles, adaptations, and important relationships among organisms (symbiosis, predator-prey dynamics, and energy transfer) that do not occur on land.

There are major threats facing marine species, including coastal development, global climate change, invasive species, overfishing, and pollution. There is growing concern that a large number of marine species may be under threat of extinction due to the convergence of these threats.

2

Ocean Science for Ocean Literacy

OBIS

The Ocean Biogeographic Information System (OBIS) is a global open-access data and information clearing-house on marine biodiversity for science, conservation, and sustainable development. More than 20 OBIS nodes around the world connect 500 institutions from 56 countries. Collectively, they have provided over 45 million observations of nearly 120,000 marine species, from bacteria to whales, from the surface to 10,900 meters in depth, and from the tropics to the poles. The datasets are integrated and can be searched and mapped by species name, higher taxonomic level, geographic area, depth, time, and environmental parameters. OBIS originated from the decade-long Census of Marine Life (2000-2010) and was adopted as a project under IOC-UNESCO's International Oceanographic Data and Information Exchange (IODE) program in 2009.

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Sam Dupont
University of Gothenburg (Sweden)

Why is ocean education/OL important to you?

I am a marine biologist and over the last decade, I've been working on the impact of global changes on marine species and ecosystems. We have overwhelming evidence that if we continue on the path we are on, there will be severe consequences for the ocean and all the services that it is providing to us.

We are at a stage where we need to make drastic changes in the way we live and share resources on the planet. That can only be achieved through individual and collective actions. Understanding the importance of the ocean, how we influence it and what can be done is the first step to drive the needed actions or accept the changes to come.

Which/When was your best OL/Ocean Science education experience?

Over the last few years, I have been reflecting a lot on how to deliver scientific information to really influence people. It is not only about increasing awareness or sharing knowledge but deliver the right information in the most efficient way. That means developing a science that relates more to values and then communicating it in a way that will help reconnect with nature and trigger emotions.

This can be a challenging task and I quickly realized that I needed to open my mind to other disciplines, including art.

I had the opportunity to work with the Swedish artist Henrik Wallgren last year. Together, we developed an activity for kids. For a few days, they agree to become the ocean and experience what it takes to be exposed to pollution. At the end of the activity, they were extremely engaged and worked toward developing solutions to be better citizens and protect the inherent beauty of the ocean.

(Activity described in: http://cecar.gu.se/digitalAssets/1621/1621211_dupont-2017.pdf)

What do you think are the future should look like for OL?

*Within the University of Gothenburg, we have developed the Centre for Collective Action Research (*http://cecar.gu.se/*). We are currently performing research on what type of information and delivery methods are optimal to drive changes in different stakeholders. Our first case study is related to the ocean. If we get better at doing and communicating research, we'll create a bridge that would allow us to increase ocean literacy.*

2

Principle 6
The ocean and humans are inextricably interconnected

Elia Metchnikoff was a Russian scientist. His discoveries underpinned a great deal of modern medical research. He discovered cells of the animal immune system by studying sea anemones and the larvae of sea stars - he was awarded a 1908 Nobel Prize. To understand the biological basis of learning and memory, in which nerve cells play fundamental roles, Dr. Eric Kandel of Columbia University studied Aplysia, a genus of medium-sized to extremely large, sea slugs. For this work, he earned a share of the 2000 Nobel Prize in medicine.

People rely on the ocean for many resources, including food that feeds billions of people and animals a day. The ocean is a source of organisms that provide new and potent medicines, as well as new products for use in biotechnology. For example, prostaglandins, hormone-like chemicals in mammals, play an important role in inflammatory responses as well as other functions. They are also present in macroalgae, where they assist with defense and communication. Rare prostaglandins necessary for human health have been found in both Indian Ocean and Caribbean Sea coral species. Current research may provide new mechanisms for predicting disease outbreaks and help reduce the risks associated with waterborne diseases.

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The ocean supports the livelihoods of more than three billion people, as well as national economies. Humankind health and wellbeing depends upon the services provided by ecosystems and their components: water, soil, nutrients and organisms. Therefore, ecosystem services are the processes by which the environment produces resources utilized by humans such as clean air, water, food and materials. A 2015 report published by the World Wildlife Fund (Reviving the Ocean Economy: The case for action—2015) has shown that the ocean is worth at least $24 trillion, and goods and services from coastal and marine environments amount to about $2.5 trillion each year. This would put the ocean as the seventh largest economy in the world if put into terms of Gross Domestic Product. Another initiative led by The Nature Conservancy, Mapping Ocean Wealth was launched in 2014. This is a global partnership of scientists, policy practitioners and financial experts mapping the world's vast ocean wealth in all its many forms. Although a global program, Mapping Ocean Wealth places great importance on local scales. Every ecosystem service comes from a complex interaction of physical, ecological and human drivers. Similarly, the way that people value ecosystems is driven by a range of social, cultural and economic factors that vary significantly based on where people live. The ocean serves as a highway for transportation of goods and people and plays a role in national security. It is a source of inspiration, recreation, and discovery. It also is an important element in the heritage of many cultures.

2

Ocean Science for Ocean Literacy

The Blue Carbon Initiative

The International Blue Carbon Initiative is a coordinated, global program focused on mitigating climate change through the conservation and restoration of coastal and marine ecosystems. Coastal ecosystems are some of the most productive on Earth. They provide people with essential ecosystem services, such as coastal protection from storms and nursery grounds for fish. They provide another integral service - sequestering and storing "blue" carbon from the atmosphere and oceans and are therefore an essential ingredient in the mitigation of global climate change.

MSP

For the last decade, the Intergovernmental Oceanographic Commission of UNESCO has been instrumental in implementing the concept of ecosystem based management through its Marine Spatial Planning approach. IOC is in a unique international position to assist in countries moving toward ecosystem-based management of the marine environment through MSP. The IOC promotes development of management procedures and policies leading to the sustainability of marine environments, as well as the capacity-building necessary for maintenance of healthy ocean ecosystems. Starting in 2006, IOC/UNESCO convened the first International Workshop on the use of marine spatial planning as a tool to implement ecosystem-based, sea use management. About 50 participants from over 20 countries attended because of their practical experience in sea use management, marine spatial planning, and ocean zoning.

Underwater Cultural Heritage

The UNESCO 2001 Convention on the Protection of Underwater Cultural Heritage is the foremost international legal reference for the protection of underwater cultural heritage.

The Convention was drafted by the international community to prevent the destruction of submerged archaeological sites, to regulate cooperation among States, and to harmonize international research standards. Above all, it was created to harmonize the protection of submerged heritage, which includes ancient shipwrecks and sunken ruins, with the protection already accorded to cultural heritage on land.

Melita Mokos
University of Zadar (Croatia)

Why is ocean education/OL important to you?

Because so many people don't have any idea of the role and the importance of the sea in their lives. Most people relate to the sea only for summer swimming, beach parties, sailing and fishing. That's all. As if those are the only things the sea provides us. Kids that live on the coast have very little or no knowledge about marine life at all. All of this bothers me. I want to change that perception. Also, as a mother, I want my kids to learn about the sea and why it is important to protect it and how to protect it. We talk about this at home a lot.

Which/When was your best OL/Ocean Science education experience?

Each marine workshop I do with small kids (preschool, primary school) is the best! Over and over again. Kids are so honest, so open-minded and show their enthusiasm, curiosity and positive reactions and each experience with them makes me feel wonderful! Those workshops are truly the best OL education experiences! I try to do those as much as possible.

What do you think are the future should look like for OL?

Implementing OL into everything: from educational systems, economy to politics, because only then will knowledge about the sea be available to society and required by society. International OL actors need to be connected to each other and develop strategies on how to do this. OL movement needs to be supported on the national levels. OL needs to become one of the priorities for decision makers. Implementation of OL should be demanded at a national level because the bottom-up approach is too slow; ocean conservation and sustainable use of marine resources cannot wait that long. UN Ocean conference Call for action and SDG14 should be the foundation of making OL relevant and obligatory at both EU and national levels. So, I believe including OL at all levels of society on a global scale and making it a priority (as soon as possible) can contribute to achieving sustainability of the world seas and oceans (or the one ocean).

2

Principle 7
The ocean is largely unexplored

Humans started exploring and learning about the ocean from the earliest ages of humanity. Archaeologists have found piles of shells, the remains of ancient "clambakes," dating back to the Stone Age. Ancient harpoons and fish hooks of bone have also been found along the coastlines of almost every continent. While they gathered food, people learned through experience which foods from the ocean were good and which were harmful. For example, the tomb of an Egyptian pharaoh bears a warning against eating poisonous puffer fish. Ancient people used marine organisms for more than food. Snail shells were used for necklaces at least 75,000 years ago. In using marine resources, coastal peoples in virtually every culture developed a store of practical knowledge about marine life and the ocean.

Everyday lives are connected to the ocean depths. There are challenges and opportunities in this previously hidden realm, and yet, despite the size and importance of the ocean, less than ten percent of it has been explored. The entire ocean floor has been mapped with a 5km resolution, but less than 0.05 percent of the ocean floor has been mapped to a level of detail useful for detecting important ocean features such as the spires of undersea volcanic vents. That global map of the ocean floor is therefore less detailed than maps of Mars, the Moon, or Venus.

Luckily new technologies, sensors, and tools are expanding our ability to explore the ocean system. Scientists are relying more on satellites, drifters, buoys, and subsea observatories.

Moreover, ocean exploration is truly interdisciplinary, and there is more close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, and social scientists. This collaboration is enhancing the understanding of the ocean and its processes and assisting researchers in developing innovative methods to further study the ocean.

2

Ocean Science for Ocean Literacy

GEBCO

The General Bathymetric Chart of the Oceans (GEBCO) aims to provide the most authoritative, publicly-available bathymetry data sets for the world's ocean.
GEBCO consists of an international group of experts who work on the development of a range of bathymetric data sets and data products, including gridded bathymetric datasets, a world map, and Gazetteer of Undersea Feature Names. GEBCO is involved in training a new generation of scientists in ocean bathymetry through the Nippon Foundation/GEBCO.

Emily King
Xiamen University (People's Republic of China)

Why is ocean education/OL important to you?

I feel that with the way things are progressing in the world today, the only chance we have is to make sure people are more informed about science and the environment. And not only to make them more informed but to give them the most accurate information possible that is based on good science. Given that we know less about the ocean than we do the moon yet, the ocean is the life support system of the planet, creating a more literate society is crucial to not only our survival but, our happiness and well-being as a species and as individuals..

Which/When was your best OL/Ocean Science education experience?

There are two. The first; one of the middle school students who attended my first summer camp 5 years ago not only went on to study marine sciences at Xiamen University but also volunteered to be an undergraduate mentor/camp counselor for this year's program.

The second moment occurred a few weeks after our annual Ocean Science Day. We were contacted by the parent of a 6/7 year old student. The family had attended the day and the child was very interested in our table about plastics in the ocean-so much so that he wanted to do a presentation for his primary school class on it. The parent contacted us asking for help with materials.

For those of us working in education, especially environmental education, we will not know if our efforts have been truly successful till after we are gone, as it's the actions of subsequent generations that are a measure of our success or failure. But moments like those two above help keep me motivated and hopeful for the future

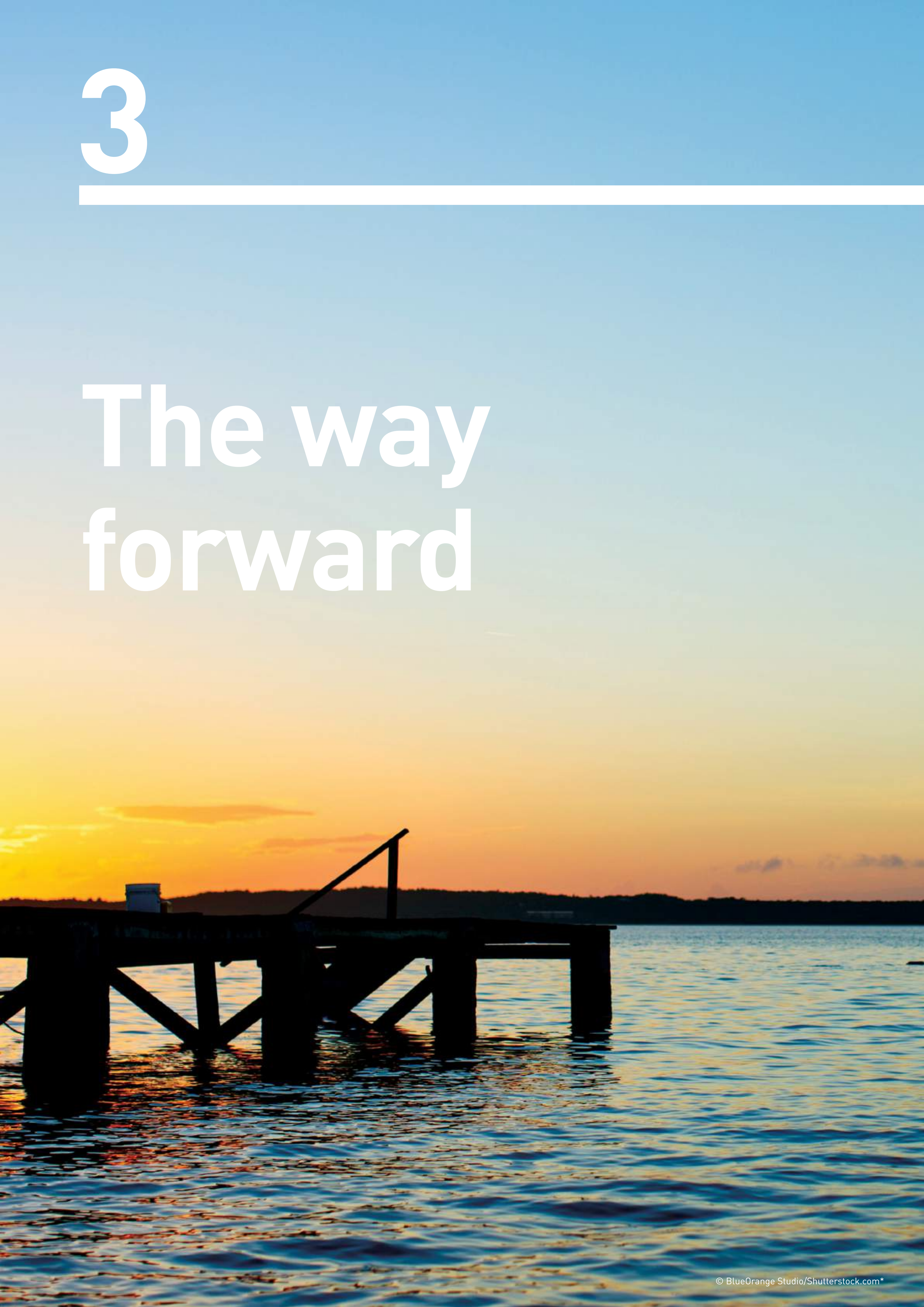
What do you think are the future should look like for OL?

I'm not sure what the future will be for OL. I do think that we need to be a little careful. It seems everyone is working on regionally specific ocean literacy points - and that is good and relevant; people need to understand their backyard before they can understand the world. I just hope that we don't get so wrapped up in developing locally relevant information that we forget to tie it into the big/overall picture.

I also think that we need to make sure to spread OL to those people/places that aren't near the ocean. This may already occur but maybe we can better coordinate the efforts.

3

The way forward



3

The way forward

3

It's not about the UN, it's not about governments, it's not about civil society or private sector or scientific community. It's all of us in this together. (Peter Thomson, UN Special Envoy for the Oceans)

3.1 Building a civic relationship with the ocean

The 2005 Ocean Literacy guide published in the USA was created with a very specific purpose. The purpose and design criteria were to establish the ocean science content that could be used to teach science in schools in the USA.

As the idea of "ocean literacy" has moved to Canada and to Europe the definition has changed. Both Canada and Europe state that the definition of ocean literacy is the ocean's influence on us and our influence on the ocean. This shift from "you" and "your" to "us" and "our" indicate that words and language matter. The EU Sea Change project too has changed the definition of what an ocean-literate person can do from "understanding the essential principles and fundamental concepts" as listed in the US guide to "understanding the importance of the ocean to humankind". These subtle but significant shifts in language underscore the need for each country and region to take the idea of ocean literacy as being an understanding of individual and collective mutual relationships with the ocean, that has local relevance. Ocean literacy should be understood as the development of a civic relationship with the ocean.

3

Looking to future work it is hoped that ocean literacy will embrace all subjects, not only science, but also art, music, archaeology, culture, geography, and that definitions, principles and concepts will be adapted and developed to make it relevant locally. For example, a group from the Mediterranean have created Mediterranean Sea Literacy that reflects its region's culture, history, and traditions. Similar efforts are beginning around other "seas" in Europe, such as the North and Baltic Seas. These adaptations and developments transcend purely ocean science. For Ocean Literacy to be truly transformative, all voices and all subjects need to be included. For example, absent from the work so far are the voices of indigenous peoples, traditional knowledge, and communities in Small Island Developing States (SIDSs).

The Ocean Literacy for All initiative will encourage wide participation in the future of ocean literacy, including the engagement of individuals from different sectors of society.

The future of the initiative *The Ocean Literacy for All* , must be trans-disciplinary, locally relevant, have representation from all voices, include all subjects, and be helpful in the broadest possible way around the world

3.2 The challenge: building partnerships within current ocean governance

The year 2017 will be remembered as a milestone for ocean action. The international community came together in New York for the first ever UN conference on the ocean where close to 1,400 voluntary commitments were announced to advance the implementation of SDG14. These commitments can be seen as important vehicles to mobilize and share knowledge, expertise, technologies, and financial resources.

Furthermore, in July 2017, during the final meeting of the Preparatory Committee established by UN General Assembly resolution 69/292: *"Development of an international legally binding instrument under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction"* countries around the world have taken the first step to protect the high seas. The UN Member States recommended starting the negotiations to create marine protected areas in waters beyond national jurisdiction. The high seas are responsible for nearly half of the ocean's biological productivity, and their health is closely linked to the health and resilience of coastal regions.

The European Union organized the fourth edition of the Our Ocean Conference in Malta. World leaders gathered together, transforming the challenges ahead into an opportunity for cooperation, innovation and entrepreneurship.

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The global ocean movement that is being created through these events, and through the development of these commitments, highlights the need for creating multi-sector and multi-disciplinary partnerships in the search for innovative and sustainable solutions.

The following words from the Global Ocean Commission report lend support to efforts in increasing ocean literacy, "*The task of saving the global ocean is one that no government or company or individual can achieve alone*."

Moreover, as ocean issues are deeply rooted in individual and collective behavior with respect to marine resources, one of the challenges of ocean literacy is to define ways to encourage behavioral change to foster the creation of ocean citizenship.
Ocean citizenship describes a relationship between human being's everyday lives and the health of the coastal and marine environment. As such, individuals have a responsibility to make informed lifestyle choices to minimize this impact. In doing so, the actions of individuals can contribute to the amelioration of large-scale problems.
Ocean literacy embodies the idea that if humans were more educated about the ocean, we would be more likely to respect the limits, in terms of sustainability, of the marine ecosystems and their resources.

While education and traditional advertising can be effective in creating awareness, numerous studies document that behavior change rarely occurs as a result of simply providing information, but there must also be initiatives delivered at a community level focusing on removing barriers to an activity while simultaneously enhancing the activity's benefits.

In this sense, both formal and non-formal ocean education endeavors, should be conceived as trans-disciplinary forms of ocean literacy. Ocean literacy initiatives should not only be confined to ocean science, but should also include experiential learning, knowledge of personal and social responsibility, and understanding of the roles of governance and communication in moving from knowledge to action.

Good ocean governance in the twenty-first century requires: stewardship of life-support systems and ecosystem services, accountability, transparency, informed opinion, national and local governmental commitment, interdisciplinary coordination and cooperation, and the development of integrated ocean policies.

The challenge of ocean literacy is therefore, to join science with the emotional attachment to nature, and integrating this into the indispensable role of governance by connecting worlds of thought and action for the purpose of promoting ocean sustainability. Developing and sustaining innovative approaches to ocean governance will require improvements in global ocean literacy.

This challenge requires a form of governance which is made of formal and informal networks of governmental, nongovernmental, and international organizations using strategies that go far beyond conventional policy-making. Such forms of governance require and depend on the empowerment of communities and networks of business, universities, research centers, and civic groups to share the responsibility for addressing urgent threats. Interesting examples of these types of partnerships are emerging around the world.

These partnerships aim to represent a meeting point between the demand and the offer of scientific knowledge and information, e.g. between the scientific community and the private sector, by organizing common activities in the marine and maritime sector.

Increasingly, ocean governance will be about empowering collaborations, which tackle emerging issues and define new strategies, this will depend on how problems are framed and narratives are constructed. Real world strategies employ multiple approaches and a mix of strategies, market (e.g. carbon pricing) and policy (e.g. incentives for renewable energy) together with information and education campaigns, and promotion of new technology and research.

Ocean literacy approaches could facilitate this kind of governance by incorporating explicitly environmental, social and economic concerns about ocean issues and resource into management, and political literacy about governance, in particular deliberative and democratic forms of governance.

To summarize, one could say that ocean literacy should be conceived within a larger ocean sustainability framework, promoting not only the understanding of ocean knowledge but also the understanding of how to govern marine ecosystems in a sustainable manner.

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3.3 A global framework for ocean sustainability: SDG14

The 2030 Agenda for Sustainable Development is a plan of action for people, planet and prosperity. In this Agenda, there are 17 Sustainable Development Goals [1] with 169 associated targets which are integrated and indivisible. World leaders have never before pledged common action and endeavor across such a broad and universal policy agenda.

The aim is to resolve to build a better future for all people, including the millions who have been denied the chance to lead decent, dignified and rewarding lives and to achieve their full human potential.

Sustainable Development Goals

https://sustainabledevelopment.un.org

Goal 1	End poverty in all its forms everywhere
Goal 2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
Goal 3	Ensure healthy lives and promote well-being for all, at all ages
Goal 4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
Goal 5	Achieve gender equality and empower all women and girls
Goal 6	Ensure availability and sustainable management of water and sanitation for all
Goal 7	Ensure access to affordable, reliable, sustainable and modern energy for all
Goal 8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
Goal 9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
Goal 10	Reduce inequality within and among countries
Goal 11	Make cities and human settlements inclusive, safe, resilient and sustainable
Goal 12	Ensure sustainable consumption and production patterns
Goal 13	Take urgent action to combat climate change and its impacts*
Goal 14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
Goal 15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
Goal 16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
Goal 17	Strengthen the means of implementation and revitalize the global partnership for sustainable development

The package of ocean and seas issues reflected in SDG 14, with seven targets and three provisions on means of implementation, is crucial to shaping global ocean actions. SDG14 focuses on human interactions with the ocean, seas, and marine resources. It is underpinned by targets addressing conservation and sustainable use of the ocean, seas and marine resources, including coastal zones, and targets referring to capacity building and ocean governance. SDG14 and its seven targets and three means of implementation are aimed at an urgent need to transform human behavior toward sustainable practices when exploiting marine resources and taking action to preserve productive and resilient oceans and seas. The seven targets largely reflect commitments under other international frameworks, such as the commitment to maintain or restore fish stocks to levels that can produce maximum sustainable yields (made in 2002 under the Johannesburg Plan) or the commitment to conserve at least 10% of marine and coastal areas by 2020 (provided under the CBD Aichi Target 11). However, the 2030 Agenda for Sustainable Development puts use and conservation of the ocean and its resources, including coastal areas, into the wider sustainable development context for the first time. The ocean space, in general, and SDG14 in particular, have a cross-cutting role in the 2030 Agenda and SDG14 interacts with all 16 other SDGs. The nature and intensity of these interactions is highly context-specific and differs across the SDGs and their associated targets (**Table 3**).

The global indicator framework was developed by the Inter-Agency and Expert Group on SDG Indicators (IAEG-SDGs) and agreed to, as a practical starting point at the 47th session of the UN Statistical Commission held in March 2016. The report of the Commission, which included the global indicator framework, was then taken note of by ECOSOC at its 70th session in June 2016.

Targets	Indicators
14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	**14.1.1** Index of coastal eutrophication and floating plastic debris density
14.2 By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans	**14.2.1** Proportion of national exclusive economic zones managed using ecosystem-based approaches
14.3 Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels	**14.3.1** Average marine acidity (pH) measured at agreed suite of representative sampling stations
14.4 By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics	**14.4.1** Proportion of fish stocks within biologically sustainable levels
14.5 By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information	**14.5.1** Coverage of protected areas in relation to marine areas
14.6 By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiation	**14.6.1** Progress by countries in the degree of implementation of international instruments aiming to combat illegal, unreported and unregulated fishing
14.7 By 2030, increase the economic benefits to Small Island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism	**14.7.1** Sustainable fisheries as a percentage of GDP in small island developing States, least developed countries and all countries
14.A Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries	**14.A.1** Proportion of total research budget allocated to research in the field of marine technology
14.B Provide access for small-scale artisanal fishers to marine resources and markets	**14.B.1** Progress by countries in the degree of application of a legal/regulatory/policy/institutional framework which recognizes and protects access rights for small-scale fisheries
14.C Enhance the conservation and sustainable use of oceans and their resources by implementing international law as reflected in UNCLOS, which provides the legal framework for the conservation and sustainable use of oceans and their resources, as recalled in paragraph 158 of The Future We Want	**14.C.1** Number of countries making progress in ratifying, accepting and implementing through legal, policy and institutional frameworks, ocean-related instruments that implement international law, as reflected in the United Nation Convention on the Law of the Sea, for the conservation and sustainable use of the oceans and their resources

Table 3. Sustainable Development Goal 14

3

3.4 Embarking on the path toward ocean sustainability

In order to develop relevant formal, and non-formal, educational paths which tackle the current ocean sustainability challenges, all educational institutions – from preschool to tertiary - can and should consider it their responsibility to deal intensively with matters of sustainable development and to foster the development of sustainability competencies.

However, when it comes to marine education, various issues are described in literature.

The field of research in marine science education is still relatively new and undeveloped. So far, not much interest has been given to publishing research in marine education [2].

This lack of research in the field of marine education can be associated with some of the main challenges of marine education. First and foremost, in many regions, the ocean is not included as part of schooling [3], [4], [5]. This challenge can partially be understood as a result of the difficulty of accessing the ocean. Few people live close to the ocean, which brings about a situation where first-hand exploration of the ocean as part of formal instruction becomes a challenge in terms of time, safety and budget [3]. Even when citizens are on the seashore, most of the marine environment remains hidden under the surface and far away from the coasts, leading to a situation where only a small fraction of the marine diversity and processes can be encountered and directly experienced. As expressed by Longo and Clark "the ocean is commonly viewed as something far removed from human society. In some ways, it is deemed "out of sight, out of mind" [6].

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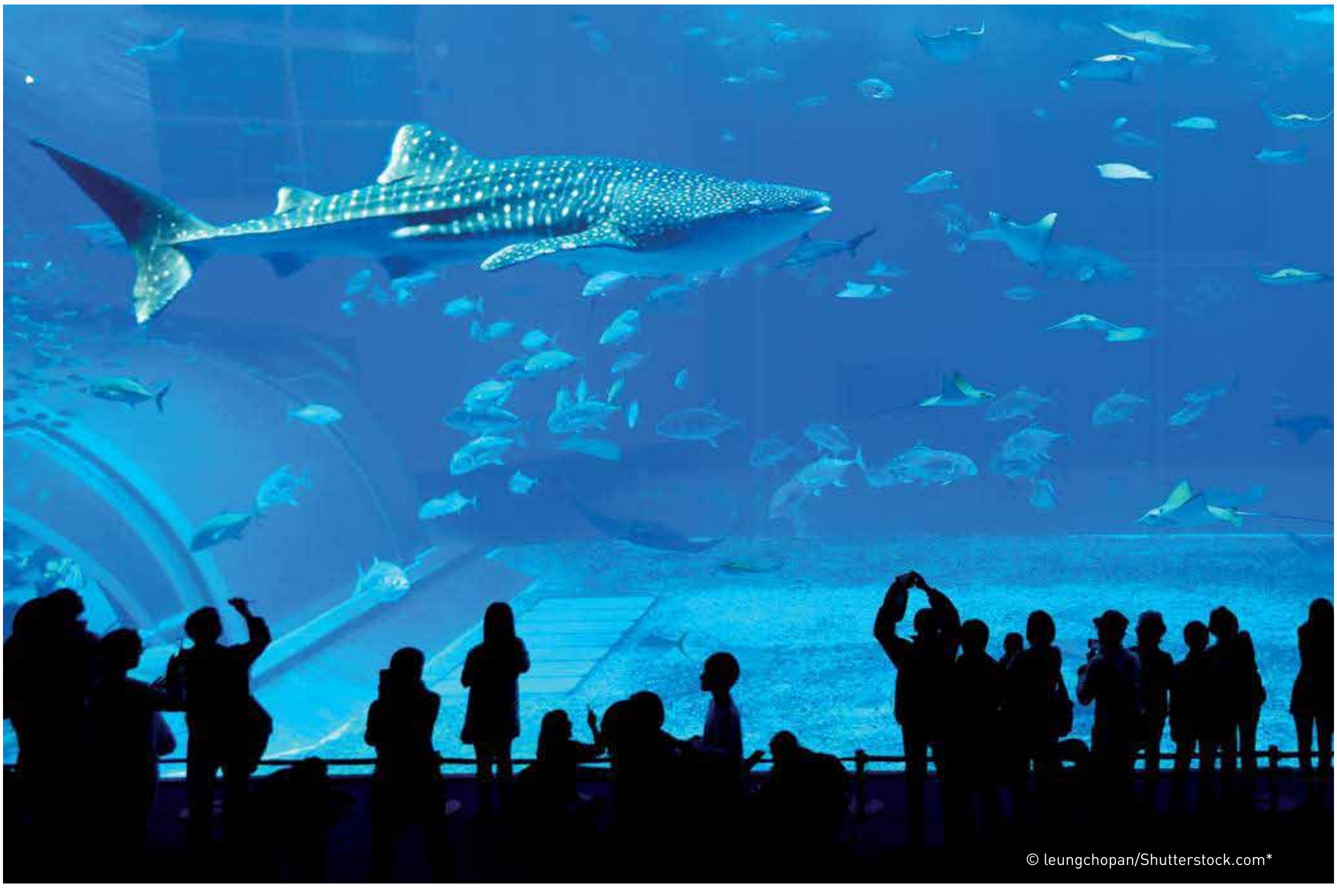

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Another challenge comes from the inherent complexity of marine environmental issues making it arduous to understand. The functions of the marine environment are rooted in intricate connections among ecological, chemical, physical, biological and social processes [7]. This interplay of various components is made even more complex by the fact that there is only one ocean covering most of the surface of the planet. To understand this massive three-dimensional system, one needs to be able to navigate all the way from small-scale observations to macro-issues in order to grasp connections such as the importance of microscopic organisms (e.g. microbes) in the context of worldwide scale phenomena (e.g. carbon cycle).

In order to address the distance between the students and the ocean, researchers have explored the impact of direct contact with the marine environment either through fieldtrips to the seashore [8], [9] or through visits to the local zoo/aquarium [10].

While Cummins and Snively [8] and Greely [9] argued that experiential learning and direct contact with the marine environment through field trips to the seashore lead to a significant increase in knowledge and positive attitudes toward the ocean, Sattler and Bogner [10] also argues that field trips to the zoo give citizens access to ecosystems and animals that they would never be able to encounter in their everyday life and conclude that aquaria can supplement formal education in terms of environmental education.

While these three studies strongly advocate for field trips, they do not offer solutions for populations living far away from the shore or an aquarium. A solution to this challenge may be found in digital technologies that hold the potential to mimic the exploration of the marine realm.

For the population too distant from a public aquarium, Tarng and his colleagues [11] created a virtual marine museum for elementary education in Taiwan (China). Through observation and interviews, the authors demonstrated that students were interested in the virtual museum and considered it more appealing than a textbook. The authors also reveal that the teachers encountered technical problems that could make students lose patience or interest. However, since this study is almost ten years old, one can argue that this kind of technology has become much more user-friendly and stable, thus reducing the occurrence of the technical challenges reported.

More recently, researchers investigated an immersive virtual environment where users wore a head mounted display to reveal the role of corals on a rocky reef while exploring how ocean acidification endangered the marine life around them [12]. The authors argue that digital technology has the potential to engage individuals with marine environmental issues. Marine educators and researchers have also investigated how to help students grasp the complexity of marine environment issues by developing hands-on experiments and online instructions where students can manipulate real-time marine data in order to understand the interconnectedness of the different parameters involved.

The Center for Microbial Oceanography: Research and Education (C-MORE) designed and tested a series of hands-on kits containing all supplies, paper and electronic materials (e.g. reading, video, presentations) needed to run the activities. The kits, targeting audiences from elementary to high schools, were loaned to teachers for free through a system of local libraries situated in four US states (Hawaii, California, Massachusetts and Oregon). The quantitative and qualitative data collected from these evaluations indicated a high degree of satisfaction among the teachers. Pre- and post-surveys also showed that even two weeks after instruction, significant knowledge was retained [13].

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While hands-on activities are extremely valuable in teaching practices, some experiments are difficult to run in a classroom due to safety, time or budget issues. In this respect, virtual laboratories offer an important means to conduct experiments and for understanding the interplay among different marine processes.

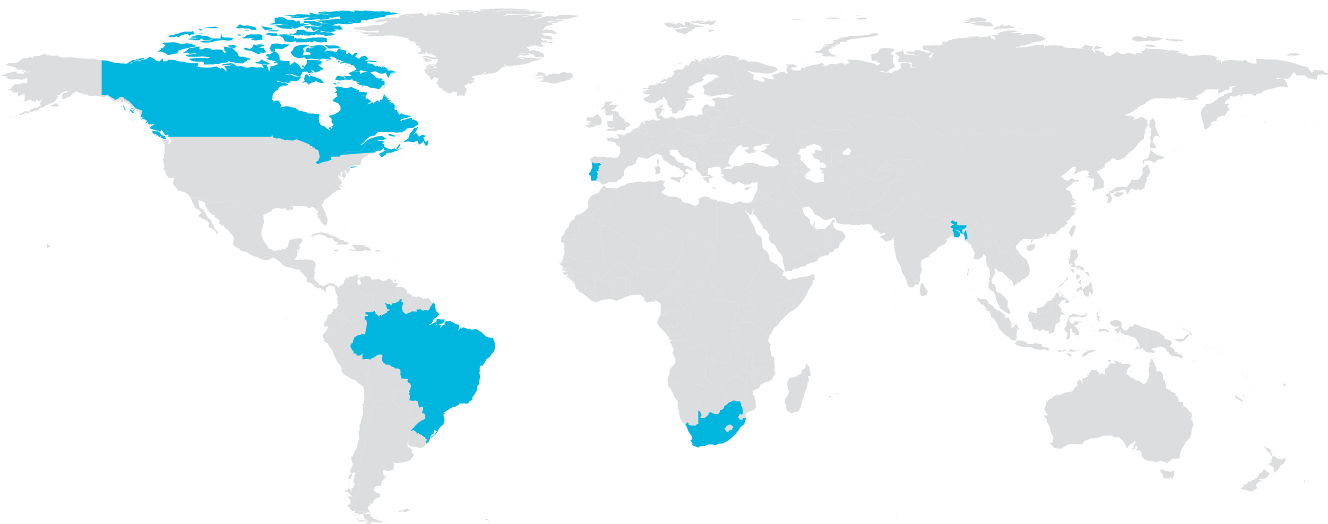
Several studies [14], [16], [17], have investigated the use of a virtual laboratory (as a stand-alone activity or combined with further instructional activities) on ocean acidification.

This virtual laboratory makes it possible for students to learn about and to test the effect of ocean acidification on marine larvae and to reflect on the cascading effect a modification of the acidity would have on the food chain and the whole ecosystem. A preliminary study [14] investigated the gain of knowledge among Swedish and Californian high school students before and after using the virtual laboratory. The conclusion was that the virtual lab seemed to promote understanding of ocean acidification.

Later on, a large-scale research study investigated how students pick up concepts and modes of reasoning after using the aforementioned virtual laboratory [16]. Since approximately half of the students improved their understanding after using the virtual lab, Petersson and her colleagues argued that the virtual lab seems to have the potential to trigger learning about how to design an experiment relating to a marine problem.

These are just few solutions developed by marine educators around the world to overcome the challenges of teaching and learning about the ocean. Marine education research is still anecdotal, impeding progress toward innovative marine education solutions. In that respect, it is time for marine education to become a more prominent topic of research, as marine education should be important as the ocean itself is for humans [15].

3.4.1
Showcasing successful stories



In the following section, some successful stories of partnerships that have developed ocean literacy programs and projects, are presented. These examples showcase the importance of building collaboration amongst governmental, educational, and private institutions to develop ocean literacy activities.

The key factors in these types of partnerships are:

The promotion of the adoption of a wider approach to ocean literacy, i.e. an approach that not only targets formal education programs but that also fosters a change in the way society deals with the ocean and its resources.

The role of institutions, such as aquaria, foundations, national agencies, and higher education institutions, is underlined. They can be seen as powerful agents of change and as a source of inspiration for those interested in developing ocean literacy programs.

The importance of sharing experiences, information, good practices across different countries and regions is shown as the most effective way to inspire new approaches and strategies to ocean literacy that are locally relevant but globally interconnected.

3.4.1.1
THE TWO OCEANS AQUARIUM, CAPE TOWN
(South Africa)

The Two Oceans Aquarium opened in 1995 and has since become one of South Africa's top tourist destinations. The Aquarium is very committed to education and has been visited by over 1 million school group children. In the 2016 calendar year, the aquarium welcomed 72,000 children in school groups. The Aquarium's Education Center has become a significant partner to the formal education landscape in South Africa, and internationally. Over the last 15 years a number of educational activities have been developed within the aquarium which strongly support the South African Curriculum.

These include courses that cover a variety of goals, ranging from introducing science in a fun way, to inspiring school students to select maths and science courses during their final year of high school (matric school), and to inspire students to select marine sciences careers. Courses include topics in Marine Biology, Oceanography, Environmental Sustainability and Human Interactions with the Ocean. Included, are the essentials of volunteering and running environmental eco-clubs at their schools. Over time, the aquarium educational unit has been approached by School Teachers and District Subject Advisors to use the content of courses and to write a Marine Sciences Curriculum and Assessment Policy Statement (CAPS) to form part of the South African Further Education and Training (FET) grade 10-12 and matric qualification. After consulting widely, it was decided that this would be a service from which the South African community, particularly students wishing to participate in the Ocean Economy, could benefit enormously. The program will be launched in 2018.

3.4.1.2
BLUE GREEN FOUNDATION
(Bangladesh)

The Blue Green Foundation was established by a group of volunteers, ocean scientists and educational professional in 2015. The aim of the foundation is to promote the sustainable use of ocean resources in Bangladesh, and in particular, the Bay of Bengal. Blue economy is seen as an important tool and approach to unlock the potential of the country's ocean space. The Foundation promotes the local implementation of SDG14 through ocean education as a tool to empower planners, policy makers, social and political leaders and next generation ocean citizens. The work of the foundation was inspired by an exchange of experiences with ocean literacy experts from different regions and national networks that had already been created. Initially, the foundation organized grassroots events and local activities. However, it was soon realized that to foster a change in the relationship between people and the ocean it was necessary to develop longer term programs linked to formal education institutions. A nationwide Ocean Literacy campaign with a school project was launched with the aim to boost the mission of Ocean Literacy, developing an Ocean Science Education Curriculum for K-12 classes. The program incorporates relevant ocean content into existing curricula, and aims organize numerous activities such as oceanographic campaigns for school students; the establishment of an ocean library; the development of a Bay of Bengal Aquarium; celebration of World Ocean Day; seminars, symposia, workshops, training programs, summer schools, and other outreach programs, such as beach cleaning campaigns to engage not only with schools but also with all the other segments of the society.

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3.4.1.3
THE BLUE SCHOOL
(Portugal)

The project called 'Blue school PT' was developed and created with the goal of improving the level of Portuguese citizens' ocean literacy. In agreement with the national educational agenda, the Blue School intends to differentiate those schools that deal with ocean content in their curriculum from those schools that are committed to engagement with the communities to promote ocean literacy. In the implementation of the activities a blue school relies on partnerships with a great variety of entities connected to the ocean highlighting the transversal and cross-cutting characteristics of ocean issues. Schools should develop ideal conditions so that children, youth and teachers can reach higher levels of Ocean Literacy, becoming agents of knowledge with an active role in the school community and in society at large. A Coordination Commission that was formed by the Directorate General for Maritime Policy (DGPM), the Oceanário de Lisboa, and Ciência Viva works together with a scientific and a pedagogical Commission that analyzes the applications of those schools willing to start the program, and validates the final decision.

Figure 1. Escola Azul

3.4.1.4
CIÊNCIAS DO MAR I
(Brazil)

In 1972, the Interministerial Commission for Sea Resources (CIRM) was created in Brazil with the purpose of coordinating the matters related to the achievement of the National Policy for the Resources of the Sea (PNRM) as well as managing the Brazilian Antarctic Program (PROANTAR). The perception that educational institutions, undergraduate and postgraduate programs, and research groups which studied the sea in Brazil, fell short of the national need and revealed the urgency for actions that would strengthen human resource training in Marine Sciences. For this reason, CIRM created the "Consolidation and Expansion of Research Groups and Graduate Studies in Marine Sciences". This is a program that aims to support, consolidate, and evaluate personnel training in Marine Sciences, through undergraduate and postgraduate courses (PPG-Mar). PPG-Mar is structured with some working groups (WGs) that not only consider issues related to ocean research but also consider ocean literacy and environmental education. In particular, the WG on ocean literacy identifies the Brazilian key stakeholders for Ocean Literacy, e.g. marine research institutions, public regulatory institutions, maritime industry, aquariums and NGOs, and provides a forum for facilitating the communication among these groups. A platform to share educational resources, organized by grade level, was also developed to facilitate the development of ocean literacy programs in Brazilian schools.

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3.4.1.5
OCEAN FRONTIER INSTITUTE
(Canada)

The Ocean Frontier Institute (OFI) [18] is an international hub for ocean science that brings together researchers and institutes from both sides of the North Atlantic to understand the changing ocean and create safe, sustainable solutions for ocean development. OFI represents a partnership among Dalhousie University, Memorial University of Newfoundland and the University of Prince Edward Island in Atlantic Canada, as well as with eight international organizations in five countries (Ireland, Norway, Germany, France, USA). The support of partners in the Government of Canada's federal laboratories, the Royal Canadian Navy, National Film Board of Canada and national and international industry, will establish Canada as a global leader in transformative ocean research.

Through participation in Ocean School, OFI supports the development and delivery of resources and programs to advance ocean literacy.
Ocean School is an educational and public engagement initiative that uses innovative learning and storytelling techniques to foster ocean literacy. A joint initiative of Dalhousie University and the National Film Board of Canada, Ocean School focuses on ocean science, technology and innovation while also providing insight into the broader economic, social, environmental, and cultural dimensions of the human relationship with the marine environment. Ocean School's objectives are to contribute to an ocean literate citizenry in Canada and around the world; to foster critical thinking and problem-solving skills by using innovative educational approaches and the scientific method; and to utilize emerging technologies to increase learner and teacher engagement in global competencies. In addition to the Ocean Frontier Institute, the initiative is supported by partnerships with Fisheries and Oceans Canada and the Nova Scotia Department of Early Education and Childhood Development.

3.4.1.6
TRANSNATIONAL AGREEMENT: AORA ALLIANCE

Ocean Literacy (OL) is a framing and foundational concept of The Galway Statement and as such, is cross-cutting among all Priority Areas of the Atlantic Ocean Research Alliance (AORA). Ocean Literacy was thus identified as one of six Priority Themes by AORA, and the OL Working Group (OL WG) was established and charged with defining a strategic path forward for Transatlantic OL (TOL), to be informed by international stakeholders representing ocean science, formal and informal education, government, marine education, business, industry and policy. The OL WG seeks alignment and collaboration among key strategic partners working among Canada, the United States (USA) and the European Union (EU) to support implementation of TOL as conceptualized in The Galway Statement. It further ensures, where appropriate, that complementary OL efforts at the global level are leveraged to support broader reach of The Galway Statement. No other entity has the "breadth and depth of knowledge" of these partnerships and their interactions and/or potential for collaborations.

Fostering cooperation and exchange of best practices in TOL has resulted in significant advances since the inception of AORA. Use of the OL Essential Principles and Fundamental Concepts as a framework for OL in the EU was a critical first step in collaborations. Additional advancements include, but are not limited to, identification and complication of key stakeholders into an online Bibliographic Reference; providing a forum for communication through organizational workshops; hosting a Massive Online Open Course on Ocean Literacy; use and transfer of best practices (i.e., Blue Schools); and engaging citizen scientists (i.e., Ocean Sampling Day and OL Videos). Deliverables are freely available and/or reside in an online directory of OL Best Practices.

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3

3.5 Final remarks

For many, the ocean is the new economic frontier. It holds the promise of immense resources, wealth, and great potential for boosting economic growth, employment, and innovation.

It is increasingly recognized as indispensable for addressing many of the global challenges facing the planet in the decades to come, from world food security to climate change, to the provision of energy, natural resources, and improved medical care [19]. However, the *First World Ocean Assessment* [20] found that much of the ocean is now seriously degraded.

A continued failure to address these problems is likely to create a destructive cycle of degradation that will ultimately deprive society of many of the benefits currently derived from the ocean. There is, therefore, an urgent need to better study and knowing the ocean to develop effective solutions [21]. Stronger cooperation and partnership between the stakeholders responsible for ocean science have to be shaped, while facilitating a faster and more effective delivery of knowledge to policy and decision-makers and society at large.

Ocean literacy is a fundamental tool to enhance ocean knowledge, but also to encourage citizens and stakeholders to have an active role in the implementation of sustainable actions on both individual and collective levels.

While at the beginning, ocean literacy was developed for the specific purpose to fit the USA science curriculum for K12, it has then, in both concept and approach, been adopted and adapted to a broader context. Ocean literacy is seen now as a way to advance sustainable production practices, to develop sound public marine policy, to promote a more responsible citizenry, and to encourage young people to start a career in the blue economy or in marine science.

This publication was meant to take stock and describe the current ocean literacy initiatives, program and projects, and to review the current approaches. However, there are still gaps to fill and challenges to meet to incorporate new cultural and disciplinary perspectives, to engage more institutions and more countries and regions. UNESCO, its IOC and its partners can offer a sharing platform to pave the way for these new processes to start and flourish.

References

[1]
SDG14
https://sustainabledevelopment.un.org/sdg14

[2]
Uyarra, M. C. and Borja, Á. 2016. Ocean literacy: A "new" socio-ecological concept for a sustainable use of the seas. *Marine Pollution Bulletin*, 104 (1-2), 1-2.

[3]
Gotensparre, S. M., Fauville, G., McHugh, P., Domegan, C., Mäkitalo, Å., & Crouch, F. 2017. *Meta-analysis of the consultation reports.* Plymouth, UK: EU Sea Change Project.

[4]
Hoffman, M., Martos D., & Barstow, D. 2007. *Revolutionizing Earth System Science Education for the 21st Century, Report and Recommendations from a 50-State Analysis of Earth Science Education Standards*. Cambridge, MA: TERC.

[5]
McManus, D.A., Walker, S.H., Cuker, B.E., Goodnight, P., Humphris, S., Kenner-Chavis, P., Reed, D., Robigou, V., and Schubel, J.R. 2000. Center for ocean science education excellence (COSEE). The report of a workshop sponsored by the National Science Foundation. Retrieved from www.cosee.net/files/coseenet/COSEE_Report_2000.pdf

[6]
Longo, S. B., & Clark, B. 2016. An ocean of troubles: Advancing marine sociology. *Social Problems, 63*(4), 463–479.

[7]
EurOCEAN. 2014. *Rome Declaration*. Rome, Italy.

[8]
Cummins, S., & Snively, G. 2000. The effect of instruction on children's knowledge of marine ecology, attitudes toward the ocean, and stances toward marine resource issues. *Canadian Journal of Environmental Education, 5*, 305–326.

[9]
Greely, T. 2008. *Ocean literacy and reasoning about ocean issues : The influence of content, experience and morality.* University of South Florida.

[10]
Sattler, S., & Bogner, F. X. 2016. Short- and long-term outreach at the zoo: cognitive learning about marine ecological and conservational issues. *Environmental Education Research*, 4622 (February), 1–17.

[11]
Tarng, W., Change, M. Y., Ou, K. L., Chang, Y. W. & Liou, H. H. 2008. The development of a virtual marine museum for educational applications. *Journal of Educational Technology Systems 37*(1), 39–59.

[12]
Ahn, S. J. G., Bostick, J., Ogle, E., Nowak, K. L., Mcgillicuddy, K. T., & Bailenson, J. N. 2016. Experiencing nature: Embodying animals in immersive virtual environments increases inclusion of nature in self and involvement with nature. *Journal of Computer-Mediated Communication, 21*, 399–419.

[13]
Foley, J., Bruno, B., & Tolman, R. 2013. C-MORE Science Kits as a Classroom Learning Tool. *Journal of Geoscience Education, 61*, 256–267.

[14]
Fauville, G., Hodin, J., Dupont, S., Miller, P., Haws, J., Thorndyke, M., & Epel, D. 2011. Virtual ocean acidification laboratory as an efficient educational tool to address climate change issues. In L. Filho (Ed.), *The economic, social and political elements of climate change* (pp. 825-836). Berlin, Germany: Springer.

[15]
Fauville, G. 2017 Digital Technologies as Support for Learning about the Marine Environment: Steps Toward Ocean Literacy. Doctoral thesis. University of Gothenburg, Sweden.

[16]
Petersson, E., Lantz-Andersson, A., & Säljö, R. 2013a. Exploring nature through virtual experimentation. Picking up concepts and modes of reasoning in regular classroom practices. *Nordic Journal of Digital Literacy, 3*(8), 139–156.

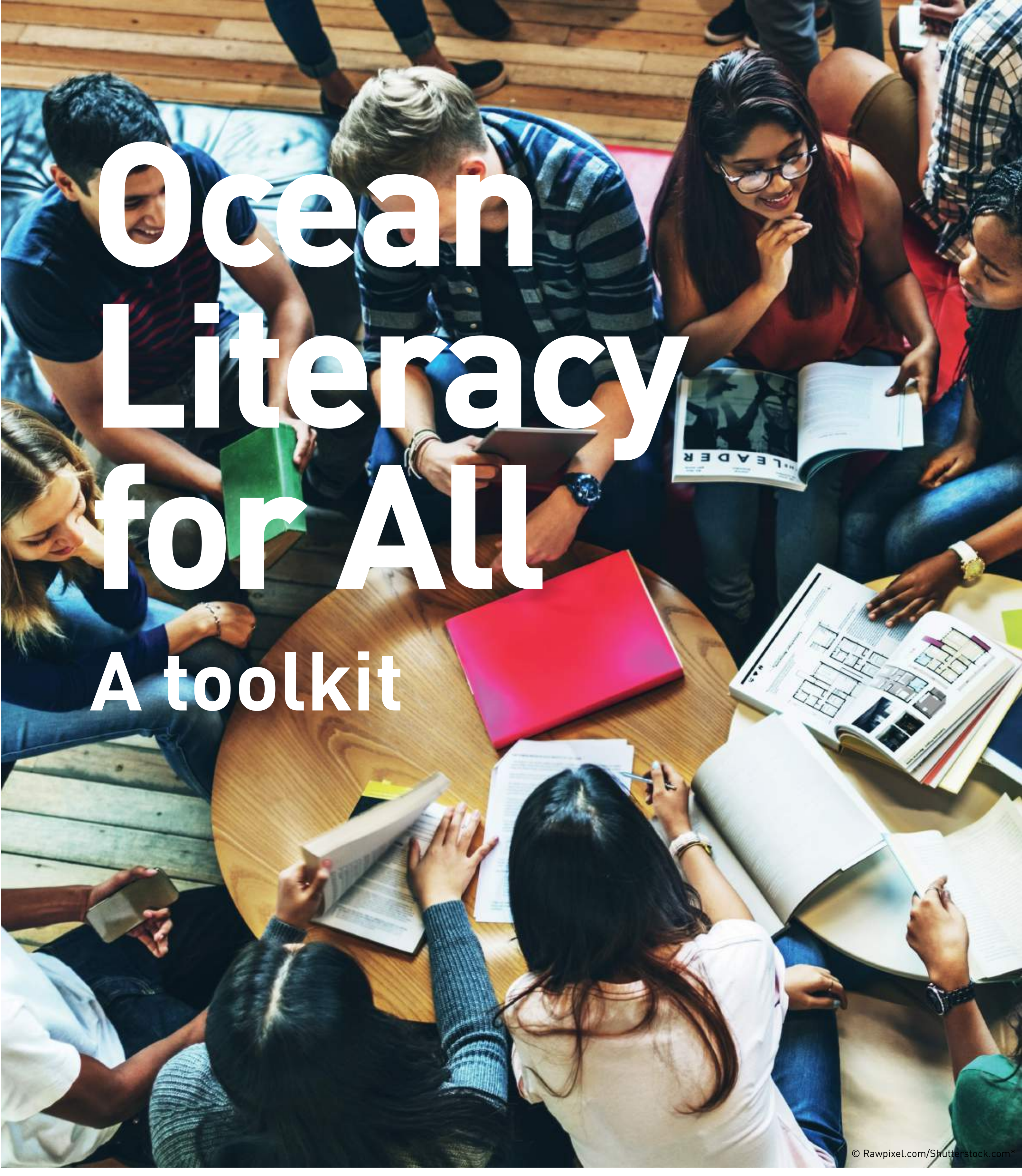
[17]
Petersson, E., Lantz-Andersson, A., & Säljö, R. 2013b. Virtual labs as context for learning: Continuities and contingencies in student activities. In E. Christiansen, L. Kuure, A. Mørch, & B. Lindström (Eds.), *Problem-based learning for the 21st century. New practices and learning environments*. Aalborg, Denmark: Aalborg University Press.

[18]
OFI
https://www.dal.ca/research/centres_and_institutes/ofi.html

[19]
OECD. 2016. The Ocean Economy in 2030, OECD Publishing, Paris.
http://dx.doi.org/10.1787/9789264251724-en

[20]
WOA
http://www.un.org/Depts/los/global_reporting/WOA_RegProcess.htm

[21]
UNESCO/IOC. 2017. The Ocean We Need for the Future We Want, Paris, UNESCO.
https://goo.gl/EoaYna



Ocean Literacy for All

A toolkit

ACTIVITIES

Part 2

Ocean Literacy for all – A toolkit

ACTIVITIES

Part 2

1

The multiperspective approach to ocean literacy

1

The multiperspective approach to ocean literacy

1

Education should be of a quality that provides the values, knowledge, skills and competencies for sustainable living and participation in society (UNESCO)

1.1 A new ocean literacy theory and practice

The ocean is crucial for all living organisms and ecosystems. In addition, the ocean is essential for human health and resilience, as well as for social and economic development. Political commitment, community action and many other factors, including those influenced by cultural and academic disciplines, demonstrate the multiple-perspective value of the ocean. The ocean is a shared resource, uniting people, communities and habitats across vast expanses of space and time. Developing educational activities on ocean issues also requires an emphasis on the way in which it is valued, governed and preserved. Currently, ocean contents and topics are not well represented in curricula; while they have the potential to be mainstreamed in an interdisciplinary way across many topics from science to art. In the past decade, the benefit of connecting to nature has been well documented in numerous scientific studies and publications. Collectively, this body of research shows that children's social, psychological, academic and physical health is positively impacted when they have daily contact with nature [1]. However, organizing educational activities close to, or at the ocean can be challenging from different points of view, such as security, cost and equipment requirements. In order to overcome these challenges natural history museums, zoos, and aquaria provide a safer space where teachers, students, and citizens can appreciate the intrinsic value of the ocean. These first-hand and hands-on activities are instrumental for the enhancement of the awareness of "the ocean influence on us and our influence on the ocean". To implement ocean policies that are rooted in the concept of sustainable development, such as SDG14, a culture of balancing economic growth, environmental conservation, cultural diversity and social well-being will have to be embedded through formal and informal education. The ability of educational institutions to respond to the complex expectations embedded in sustainable development can be enhanced through a multi-perspective approach to teaching and learning. A multiple-perspective approach promotes interdisciplinary and intercultural competencies as it addresses challenges to local or global sustainability. Interdisciplinary thinking allows students to use knowledge in new and creative ways.

This is the approach proposed by UNESCO in the UN's Decade of Education for Sustainable Development. It has already been applied to issues such as climate change, disaster risk reduction, and biodiversity conservation, and this publication describes its application in the context of ocean literacy.

«Intercultural dialogue contributes to sustainable development by facilitating knowledge exchange. Through combining all forms of knowledge, more sustainable practices can be developed and better solutions to current issues may be achieved» [2].

Ways of thinking are vital to a multiple-perspective approach to education for sustainable development including; systems-thinking, intergenerational responsibility, protection and enhancement of shared natural resources, awareness of driving forces, and taking on strategic responsibility. The many processes of both natural and human influences on the ocean become then accessible and meaningful to learners. Learners are guided to understanding through seven unique, but overlapping, perspectives on the relationships within the ocean system and between the ocean system and human society.

This holistic approach has the advantage of being easily adaptable to different geographic, cultural and historical contexts. The point of the multiple-perspective approach is to acknowledge that there are many sides, or perspectives, to understanding challenges related to the ocean. To fully teach or learn about Ocean Literacy complexity, each dimension (environment, society, culture and economy) must be addressed both separately and jointly. The multiple-perspective approach provides a structure that educators can use to detangle the complexities of real-life situations.

The Multiple-Perspective Tool can be used as a pathway to:

- **Learn about ocean issues from multiple bodies of knowledge,**
- **Identify and understand both personal and outside perspectives, and**
- **Apply decision-making processes to complex issues that affect personal, community, and global well-being.**

There are seven perspectives:

- **The scientific perspective**
- **The historical perspective**
- **The geographic perspective**
- **The gender equality perspective**
- **The value perspective**
- **The cultural perspective**
- **The sustainability perspective**

1.1.1 The scientific perspective

What does learning about the ocean through a scientific perspective mean?

The scientific method is based on the observation of a natural phenomenon, on the formulation of hypotheses, on the collection and analysis of data, on their interpretation and on the definition of the results to draw final conclusions. This process must be replicable and verifiable in different settings. Understanding the ocean from a scientific perspective means being able to solve complex problems by applying knowledge that is applicable to different situations and geographical contexts. Interpreting and testing different hypotheses can enhance the understanding of natural phenomena as well as the relationship with humankind.

Solving complex ocean issues such as; marine litter, ocean acidification, and rises in sea levels means understanding the biotic and abiotic processes involved, their natural and anthropogenic causes and their possible consequences. A solid scientific background will help the learners to find solutions from an individual and collective point of view. An essential element of educational activities developed with a scientific perspective is the direct observation of processes and phenomena. For example, learners can search for flora and fauna on beaches close to their village and these can be compared with global marine biodiversity data results by educators. In this way, they can familiarize themselves with real data and the scientific method using an easy, hands-on, activity. It might also be interesting to get in touch with marine scientists; educators might encourage marine scientists to organize a visit to their laboratories to participate in everyday duties. This will help them to understand what "doing science" really means.

1.1.2 The historical perspective

What does learning about the ocean through a historical perspective mean?

It is well known that the relationship between humans and the ocean has changed over time. For example, over centuries, the capacity to venture further out to sea and to reach even the deep sea has progressed in parallel with scientific and technological discoveries. In his book "The Social construction of the Ocean", Philip Steinberg presents three perspectives on human-marine interactions. The ocean space has been seen as a "resource provider, transport surface and battleground or force-field" over the centuries. This has in turn influenced the development of the ocean international regime and resource management programmes. Learners could study the history of ocean explorations from the first Viking expeditions to Iceland and Greenland in the 10th century, passing through Magellan's first Circumnavigation of the World which dates back 500 years, to modern deep sea exploration. With a historical perspective learners will understand how ocean issues have been addressed historically, how local and global communities have made ocean management decisions and what the implications of those decisions were.

1.1.3 The geographic perspective

What does learning about the ocean through a geographic perspective mean?

The tidal range in Mont Saint Michel, France, is its defining feature. Tide is a well-known ocean phenomenon that has different amplitudes in different regions of the planet. Natural or human-created ocean issues appear, and could reoccur, across a community, region, country, or continent. Challenges or processes take on different complexities when examined at a local, national or international scale. Taking into account the geographic perspective of a problem, learners gain deeper insights into the origin of a problem and potential solutions.

For example, learners could get in contact with others living abroad or in different regions within the same country. They can gather information on different beaches' morphology and different ocean phenomena, comparing them with what they can see in their surroundings. For a further step, learners could also investigate how climate change is impacting coastal and marine areas across the globe in different ways and with different consequences.

1.1.4 The gender equality perspective

What does learning about the ocean through a gender equality perspective mean?

In Zanzibar, the fortune of women is tied up with the Indian Ocean. They harvest a seaweed species which is the second most important industry after tourism. 20,000 farmers are employed in this industry, more than 90% of whom are women. This is an example of how social and cultural practices regarding access to, and use of, marine resources may affect men and women differently.

Learners can explore gender roles in decision-making using and protecting the ocean in different communities and at different levels. They can also consider how access and long-standing practices related to ocean resources, especially for domestic use, may have contributed to unexamined consequences of traditional gender roles, including differential access to education and work opportunities. Learners may consider, too, how advances in ocean management (e.g. technology) may have changed the context for traditional ocean-related gender roles (e.g. technology has replaced the need for physical strength in completing many tasks). They could also think about other examples of ways in which men and women are affected differently/in the same way by the ocean, in their community, as well as in other countries.

1

1.1.5 The value perspective

What does learning about the ocean through a value perspective mean?

In the 2015 edition of Our Ocean conference the government of Chile announced a commitment to the establishment of two Marine Protected Areas for a total amount of 1.017 square kilometers in the Nazca-Desventuradas Marine Park and in the island of Rapa Nui. In September 2017, the Rapa Nui (Easter Island) Rahui Marine Protected Area (MPA) was established to recognize the community process that has gone into the last five years. The Pew and Bertarelli Foundations worked jointly with Rapa Nui leaders on education, training and cultural exchanges with other Pacific Islanders to detect illegal fishing activities with new satellite technologies. In addition, the Rapa Nui population is aware that a healthy marine environment is directly tied to their traditions and way of life and, that thriving environment can help maintain a society's culture and traditions. Participation, understanding of different people's values, needs and perspectives on ocean issues are building blocks to develop common actions, and marine citizenship.

Learners can simulate public debates regarding real ocean issues such as the creation or enlargement of a port, or the creation of a new marine protected area. They can play the roles of the different stakeholders while bearing in mind their values and different perspectives. The focus should be put on what values are mutually supportive and what seem to be mutually exclusive. The final goal of the simulation will be to suggest possible solutions that acknowledge and respect the values expressed, in an attempt to move the community toward a common course of action.

1.1.6 The cultural perspective

What does learning about the ocean through a cultural perspective mean?

In Fiji, different communities or clans possess different coastal areas, each one called a *qoliqoli* (pronounced 'go-lee go-lee'). These are clan-owned fishing grounds that are passed down from generation to generation. Traditionally, when the chief of a village dies, a portion of the community's fishing ground is set aside as a no-take, or *tabu* (pronounced 'ta-boo') area as a token of respect for the chief. After 100 days, the area is re-opened and the community harvests fish to hold a feast to end the mourning. The power of the chief is usually measured by the abundance and size of the catch.

The Locally-Managed Marine Area Network (LMMA) is an international network of natural resource management practitioners working in Asia and the Pacific, who have joined together to share best practices, lessons learned and to amplify their community voices. LMMA work in Fiji focuses on reviving this traditional practice with tested variations in length of closure time needed to allow for spillover and seeding effects. Today, tabu areas in Fiji are being set up with the joint agreement of the chiefs and the people, unlike in the tradition following the death of a chief. The tabu imposed after the death of a chief now serves to reinforce the modern tabu area. The creation of marine protected areas (MPAs) or reserves – modern versions of the tabu system – has followed the traditional rites, with formal declaration and ceremonies performed, traditional marking of the closed area, and notification of neighboring users.

A cultural perspective is often a unique perception associated with a particular community, which may serve to separate that community from other cultural communities. A cultural diversity perspective considers the role of the ocean in the cultural community's worldview. Learners can look for stories, songs, poems, and other forms of cultural expressions for cultural perspectives. These can be from different countries or from different areas of the same country. Comparison and contrast can help to the student to understand the underlying values as expressed in the materials collected. If the cultural perspective is combined with a historical perspective, such comparisons may also be made within one given society, at different periods of time.

1

1.1.7 The sustainability perspective

What does learning about the ocean through a sustainability perspective mean?

In Kenya, a recently approved law states that producing, selling and using plastic bags is illegal and anyone in contravention of the law will risk imprisonment of up to four years, or, fines of $40,000.
This is the world's toughest plastic bag ban. The east African nation joins more than 40 other countries that have banned, partly banned or taxed single use plastic bags, including China, France, Rwanda, and Italy.

Now is the time to decide ocean we would like to have in the future. Sustainability might seem an abstract concept to learners of any age, but sustainability is about our choices, it's about our behaviors, it's about our values and it's about governmental decision. The interactions between the environment, economics, and society define ocean sustainability for ecosystems and people both today and in future. Quality of life and the projected needs of future generations should be considered, with planning for future use and growth as integral components of sustainability decisions.

Learners can identify an ocean sustainability issue (e.g. overfishing) and analyze the interaction among its environmental (species depauperation), economic (market value's distortion of some species) and societal dimensions (unemployed fishermen) and frame them into a future projection.
Possible solutions might be developed by taking into account the concept of both intra- and inter-generational equity.

2

Activities

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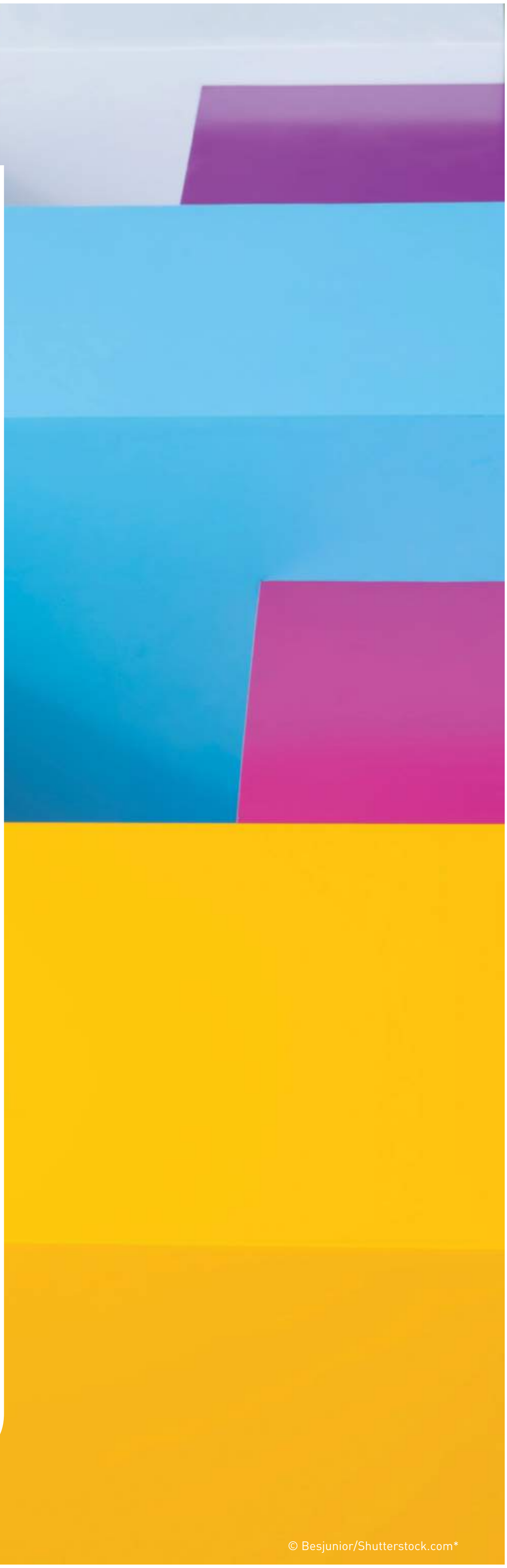
2

Activities

2.1
Structure of the activities



2

The more clearly we can focus our attention on the wonders and realities of the universe about us, the less taste we shall have for destruction. (Rachel Carson, biologist and writer)

2.1 Structure of the activities

The following sections present sixteen activities that have been adapted from existing resources available to the partner institutions of the Voluntary Commitment Ocean Literacy for All.

The activities are structured in a way that provides links with SDG14, as well as to other SDGs, and that makes reference to the SDGs learning objectives, cognitive, socio-emotional and behavioral, as defined in the UNESCO Education for Sustainable Development Goals - Learning Objectives. They refer to key competencies needed, by learners of all ages, to deal with sustainable development issues. The cognitive domain comprises knowledge and thinking skills necessary to better understand the SDG and the challenges in achieving it. The socio-emotional domain includes social skills that enable learners to collaborate, negotiate and communicate to promote the SDGs as well as self-reflection skills, values, attitudes and motivations that enable learners to develop themselves. The behavioral domain describes action competencies.

Ocean sustainability issues have to be framed at the interface between science, society, economy, policy, and environment. They are complex in nature, and therefore, they require creative and self-organized action. Citizens must learn to understand the complex world in which they live. They need to be able to collaborate, speak up and act for positive change [3]. These people can be called marine citizens. It is argued that marine citizenship requires an enhanced awareness of marine environmental issues, an understanding of the role of personal behavior in creating and resolving marine environmental issues, and a shift in values to promote marine pro-environmental behavioral choices [4].

The following activities are meant to provide tools and practices to implement this approach.
Each section includes a wide variety of activities in terms of discipline (e.g. science, art, geography, economy), ways of implementation (e.g. science labs, field trip, or drama performance), and materials needed (e.g. aquariums, lab equipment, or books and texts).

The format gives an introduction and the background information necessary for teachers to conduct the activity, as well as the steps to be followed from both the learner and the educator's perspectives. Information is also given on how to assess if the learner has reached the learning objectives or not.
Finally, information is given on how to adapt the activity to different age groups, in formal or non-formal contexts, and in different geographical settings.
Educators can adapt them according to their needs and available resources, and can also further deepen the understanding of the proposed themes through the additional references provided.

2 Activity Format

Activity Name/Title:

Time:

Source (if published) and/or author of the activity:

Target Ages:

Ocean Literacy Principle(s) addressed [5]**:**

SDG-14 target addressed [6]**:**

Link to other SDGs [7]**:**

Focus on [8]**:**
Cognitive learning objectives
Socio-emotional learning objectives
Behavioral learning objectives

Focus on, with reference to the UNESCO Education for Sustainable Development (ESD) multi-perspective approach [9]**:**

- **The scientific perspective**
- **The historical perspective**
- **The geographic perspective**
- **The gender equality perspective**
- **The value perspective**
- **The cultural perspective**
- **The sustainability perspective**

Introduction or background information/ content necessary for educators to conduct the activity

---

A list of necessary materials and included attachment to conduct activity, e.g., Learner Instruction Sheet(s), Diagrams, Maps, Tables, Data Sets, etc.:

Steps the learner will need to complete

Teaching tips and strategies, including discussion questions and answers

---

Assessment Strategies, and learning outcomes defined

Additional suggestions for conducting the activity with younger and/or older audiences and in a non-formal setting

---

Additional resources, e.g., websites, printed material, software, data sets, etc.

References used to develop the activity

2

2.1.1 The waves

The waves

120 minutes

Francesca Santoro, Selvaggia Santin

14+

6

14 LIFE BELOW WATER

14.2

4 QUALITY EDUCATION

Focus on:

Cognitive learning objectives

I. The learner understands the connection of people to the sea and the life it holds.
II. The learner knows about opportunities for the sustainable use of living marine resources according to different cultural points of view.

Socio-emotional learning objectives

I. The learner is able to argue for the importance of the ocean for cultural management.
II. The learner is able to empathize with people with a different cultural approach to marine resources and their uses.

Behavioral learning objectives

I. The learner is able to express the personal relationship with the sea.
II. The learner is able to communicate about the ocean in a meaningful way.

Focus on, with reference to the UNESCO Education for Sustainable Development (ESD) multi-perspective approach

- **The geographic perspective**
- **The value perspective**
- **The cultural perspective**
- **The sustainability perspective**

Introduction or background information/ content necessary for teachers to conduct the activity

This activity could be developed with teachers from different disciplines i.e. literature, art, drama.

- Incipit of The Waves, Virginia Woolf
  https://ebooks.adelaide.edu.au/w/woolf/virginia/w91w/

A list of necessary materials and included attachment to conduct activity, e.g., Student Instruction Sheet(s), Diagrams, Maps, Tables, Data Sets, etc.

Steps the students will need to complete

- Read the text.
- Think about the emotions that arise, and reflect on the possible use by the author of metaphors and figures-of-speech related to the ocean.
- Think about other authors or texts, including traditional stories, folktales or oral history, where ocean phenomena are used as a source of inspiration.
- Each student will produce either a text, a song, a video, or a drawing and any other artistic expression, using the ocean as a source of inspiration and/or showing the role of art as a communication vehicle to raise awareness of marine issues, e.g. marine litter, overfishing.
- The final results are presented and discussed in the class to provoke a common reflection on both the relationship between the ocean and culture and on the role of artistic expression as a communication vehicle.

2 2.1.1 The waves

Teaching tips and strategies, including eventually discussion questions

- Give a short lecture on Virginia Woolf's writing style, and on the relationship between the ocean, art and culture also by using other examples, e.g. Hemingway, Melville, Pablo Neruda, Hokusai.
- Make sure that students will be able express their personal relationship, as well as their country/region/village, with the ocean.
- Make sure that the students reflect on the role of art in communicating about the ocean.

Assessment Strategies, and learning outcomes defined

Evaluation is based on their final product as well as their discussion and ability to express themselves as marine citizens. Furthermore, it should be based on their understanding of the role of the sea and the ocean in cultural heritage and on humans.

Additional suggestions for conducting the activity with younger and/or older audiences and in a non-formal setting

- Younger students
  Use a similar but simpler text, and preferably audio/visuals formats
- Older students
  Propose a collaborative art performance and/or production e.g. a theatrical piece
- Non-formal settings
  Organize an ocean related reading club

Additional resources, e.g., websites, printed material, software, data sets, etc.

- http://www.allthewaytotheocean.com/
- http://www.underwatersculpture.com/
- https://www.tba21.org
- The Mediterranean Breviary (P. Matvejevic)

References used to develop the activity

None

2.1.2 The role of international legislation to protect the high seas

2

The role of international legislation to protect the high seas	**180 minutes** (or 3 full lessons time)	**Francesca Santoro, Selvaggia Santin**	**16+**
4, 6		14 LIFE BELOW WATER — 14.C	17 PARTNERSHIPS FOR THE GOALS

Focus on:

Cognitive learning objectives

I. The learner understands the maritime zones according to UNCLOS.
II. The learner understands the connection of many people to the sea and the life it holds, including the high seas' role as a provider of food, and its economic value.
III. The learner knows about opportunities for the sustainable use of living marine resources according to different countries' point of view.

Socio-emotional learning objectives

I. The learner is able to argue for the need to protect biodiversity in the high seas.
II. The learner is able to influence groups that engage in unsustainable use of high seas ocean resources.
III. The learner is able to empathize with people with a different culture and their approach to marine resources use.

Behavioral learning objectives

I. The learner is able to research their country's dependence on the sea.
II. The learner is able to contact their representatives to discuss marine resources use, and more specifically in the high seas.
III. The learner is able to campaign for marine biodiversity protection.

Focus on, with reference to the UNESCO Education for Sustainable Development (ESD) multi-perspective approach

- **The geographic perspective**
- **The value perspective**
- **The cultural perspective**
- **The sustainability perspective**

Introduction or background information/ content necessary for teachers to conduct the activity

This activity could be well developed with teachers from different disciplines i.e. law, biology, civics.

- Video of Prof. Dire Tladi of Professor of International Law Faculty of Law, University of Pretoria on Law of the Sea: http://legal.un.org/avl/ls/Tladi_LS.html#

A list of necessary materials and included attachment to conduct activity, e.g., Student Instruction Sheet(s), Diagrams, Maps, Tables, Data Sets, etc.

- What Are the High Seas? Why Do They Need Help? https://youtu.be/p_72ZuMf0yI
- IDDRI Policy Brief on BBNJ: https://goo.gl/yKJv6L
- IISD Summer Highlights of the 4th Session of the Preparatory Committee Established by the UN General Assembly Resolution: http://enb.iisd.org/download/pdf/enb25141e.pdf

Steps the students will need to complete

- Read the material and search for key words, terminology (e.g. marine biodiversity, marine genetic resources (MGR), marine protected area (MPA).
- Within each major group each student will choose one country to represent.
- Each student will write a short position paper for each country.
- Once students have determined their own positions, they introduce themselves to the other representatives in class and state their position.

2 2.1.2 The role of international legislation to protect the high seas

- Then informal meetings and discussions between countries occur.
- Based on conversations, negotiations, and reading position papers, students revise and refine their draft resolution.
- They present this during the last class which is a final negotiating session.

Teaching tips and strategies, including eventually discussion questions

- Give a short lecture on the UN, on international negotiation, on UNCLOS and the maritime zones, and assign background readings (see item10), presenting an overview of international high seas negotiations.
- Make sure that students choose one country to represent, bearing in mind the need to have all major groups represented (e.g. EU, G77, SIDS, GRULAC).
- Circulate their background papers and position papers.
- Make sure students get to the final draft resolution.

Assessment Strategies, and learning outcomes defined

Evaluation is based on the position papers and on the draft resolution. Furthermore, it should be based on how they reflect different positions in the use of marine resources uses and how they simulate the negation process. Assessment is also based on their oral presentation of their formal resolution, and overall class participation, as well as on their capacity to argue for marine biodiversity protection, sustainable ocean management, and an ability to use the appropriate terminology.

Additional suggestions for conducting the activity with younger and/or older audiences and in a non-formal setting

- **Younger students**
  Reduce length and focus on high seas (i.e. an area of the ocean which is not yet regulated) a more general view on the UN and the legislation process; and on UNCLOS.
- **Older students**
  Deepen the study of the legislation process, the marine resources uses and management, to produce a longer assignment including a policy brief on BBNJ.
- **Non-formal settings**
  The BBNJ negotiation could become the topic of a summer camp or International Voluntary Projects.

Additional resources, e.g., websites, printed material, software, data sets, etc.

- National Model UN: http://www.nmun.org/
- UN General Assembly structure and roles: http://www.un.org/en/ga/about/index.shtml
- How does the UN works: https://youtu.be/Qolafzc0k74
- UN Secretary General Opening Speech at the UN Ocean Conference (New York, 5 June 2017) https://goo.gl/y4QUAT

References used to develop the activity

- https://serc.carleton.edu/NAGTWorkshops/climatechange/activities/15155.html

2.1.3 Exploring the energy potential of the ocean

Exploring the energy potential of the ocean

60 minutes
(2 full lessons time)

Francesca Santoro, Selvaggia Santin

17+

1 **6**

14.1, 14.A

Focus on:

Cognitive learning objectives

I. The learner understands maritime uses, and possible synergies, and conflicts.
II. The learner understands the connection of many people to the sea and the life it holds, as a provider of food, and its economic value.
III. The learner knows about opportunities for the sustainable use of living marine resources.

Socio-emotional learning objectives

I. The learner is able to argue for sustainable ocean management.
II. The learner is able to influence groups that engage in unsustainable use of ocean resources.
III. The learner is able to understand different perspectives and approaches to marine resources use.

Behavioral learning objectives

I. The learner is able to research their country's dependence on the sea.
II. The learner is able to participate in debate processes on the marine coastal area development and to discuss the use of marine resources use.
III. The learner is able to campaign for sustainable ocean planning.

Focus on, with reference to the UNESCO Education for Sustainable Development (ESD) multi-perspective approach

- **The scientific perspective**
- **The geographic perspective**
- **The value perspective**
- **The sustainability perspective**

Introduction or background information/ content necessary for teachers to conduct the activity

This activity could be developed with teachers from different disciplines i.e. law, biology, civics.

- An OECD publication on the future of ocean economy:
- http://www.oecd.org/environment/the-ocean-economy-in-2030-9789264251724-en.htm (summary available in 25 languages)
- Video on marine renewables in Europe: https://youtu.be/f40PhfU_ZXU
- Knowledge platform with e-learning tools: http://aquaret.com/
- Resource on marine uses and potential conflicts among them: https://www.nationalgeographic.org/activity/create-a-marine-protected-area/

A list of necessary materials and included attachments for conducting the activity, e.g., Student Instruction Sheet(s), Diagrams, Maps, Tables, Data Sets, etc.

- Marine renewable research and innovation center in Chile http://www.meric.cl
- https://goo.gl/MRzHoa
- Coastal and Marine Assessment in Chile: https://goo.gl/phg82d
- Use Google Earth and select Chile (including its marine area)

2 2.1.3 Exploring the energy potential of the ocean

Steps the students will need to complete	▪ Read the material paying special attention to existing ocean uses in Chile and search for keywords, terminology (e.g. marine uses, marine spatial planning, marine protected area (MPA)). ▪ Each student will think about different ocean users and potential conflicts among them, e.g. fishermen, recreational operators. ▪ Once students have chosen the category of ocean users they want to represent, they introduce themselves to the other ocean-users in class and express their points of view. ▪ Then informal meetings and discussions between ocean users occur. ▪ The students draw various ocean uses in Chile and identify ways to promote better planning, synergies and conflict reduction mechanisms.
Teaching tips and strategies, including eventually discussion questions	▪ Let the students brainstorm on how humans use the ocean: Who does use the ocean? How do they use it? Examples of uses include: I. Fisheries II. Nature protection III. Tourism IV. Transport V. Aquaculture VI. Energy production ▪ Let the students brainstorm around marine resources and marine organisms and the ways in which they use ocean resources. Examples of use include: food, shelter/habitat, reproduction. ▪ Let the students reflect on relationships among users, both in term of synergies e.g. conservation and ecotourism, and of conflicts e.g. fisheries and transport. ▪ Define how to use the ocean space in order to favor synergies and reduce conflicts, e.g. design areas to develop multiple uses platforms including aquaculture, maritime surveillance and energy production. ▪ Discuss the results focusing on the possibility of cooperating for a sustainable use of the ocean.
Assessment Strategies, and learning outcomes defined	Evaluation is based on students' understanding of all potential spectrum of ocean uses, synergies and conflicts. Furthermore, it should be based on how they reflect different positions on marine resources, their uses, and how they are able to solve conflicts. Assessment is also based on their oral presentation, and overall class participation, as well as on their capacity to argue for sustainable ocean management, and to use their ability to use the appropriate terminology.
Additional suggestions for conducting the activity with younger and/or older audiences and in a non-formal setting	▪ Younger students Propose a simulated and simplified country map, including ocean uses and possible conflicts ▪ Older students Develop a simulated marine spatial planning game by using coding tools, e.g. MIT scratch ▪ Non formal settings Citizens simulate a marine spatial planning process
Additional resources, e.g., websites, printed material, software, data sets, etc.	▪ MIT Scratch Software: https://scratch.mit.edu/ ▪ http://msp.ioc-unesco.org/about/msp-at-unesco/ ▪ http://www.mspchallenge.info/about-us.html
References used to develop the activity	▪ https://www.nationalgeographic.org/activity/create-a-marine-protected-area/

2.1.4 Ocean currents and ocean drifters

Ocean Currents and Ocean Drifters

90 minutes

Bradley Janocha, Douglas Levin

8 -13 years

2 3

14 LIFE BELOW WATER

14.A

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

13 CLIMATE ACTION

17 PARTNERSHIPS FOR THE GOALS

Focus on:

Cognitive learning objectives

I. The learner understands major ocean currents and map them.
II. The learner models the thermocline and explains its role in water transportation.
III. The learner predicts the trajectory of a macroscopic object exposed to ocean currents.

Behavioral objectives

I. The learner identifies its role in conservation of earth's oceans.
II. The learner develops understanding and potential relationships with international school partners through launching and monitoring of a mini-boat.

Focus on, with reference to the UNESCO Education for Sustainable Development (ESD) multi-perspective approach

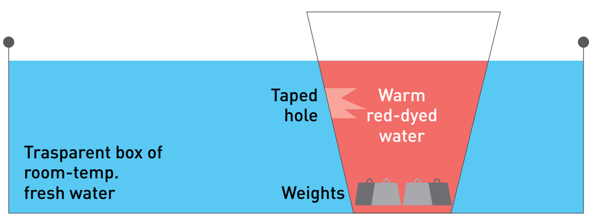
- **The scientific perspective**
- **The cultural perspective**
- **The sustainability perspective**

Introduction or background information/ content necessary for teachers to conduct the activity

A list of necessary materials and included attachment to conduct activity, e.g., Student Instruction Sheet(s), Diagrams, Map10s, Tables, Data Sets, etc.

- Water
- Microwave or hotplate
- Red dye
- Reusable towels
- Transparent plastic bins with a recommended length between 38 and 50 cm
- Transparent plastic cups or recycled water bottles
- Scissors
- Tape
- Pitcher
- Paper and colored pencils
- Internet access and projector

To prepare for this lesson, five steps must be completed: (1) create the display model, (2) fill the water pitchers, (3) prepare plastic cups, (4) print the prediction maps, and (5) unblocking the Educational Passages website.
Create the display model for the Exploration activity based on the *Exploring Our Fluid Earth* activity from the University of Hawaii (see References for this activity). Use the materials listed above and the following modified diagram to create the display.



2 2.1.4 Ocean currents and ocean drifters

After creating the display, fill a pitcher with hot water warmed on a hotplate or in a microwave. Dye the water red. This is the water you will pour into your students' cups in the Exploration activity.
Prepare the plastic cups by poking a hole below the water line.
Print the prediction maps and put in a request to unblock Educational Passages prior to implementing this lesson plan: http://educationalpassages.com/active-boat-map/.

Teaching tips and strategies, including eventually discussion questions

To have your students explore temperature's effect on water flow, use the following steps to complete part of the *Exploring Our Fluid Earth activity*.

- Break your class into pairs or teams of three and distribute paper, colored pencils, a plastic bin, two prepared plastic cups, and tape to each team.
- Instruct the teams to patch the plastic cup holes with tape, add weight to the bottom of the cups, and fill the bin with tap water.
- Go to each group; fill their plastic cup with warmed red-dyed water.
- Instruct the group to place the cup near the edge of their bin with the tape facing the opposite wall (see Preparation). Have the students sketch the model and draw their predictions as to where the water will move.
- For every group, have all teams carefully remove the tape from the plastic cups and record their observations.
- (**Figure 1**) After reviewing the previous activity's results, draw or display the following diagram and ask student to explain the graphic.
- (**Figure 2**) Distribute prediction maps to your students and instruct them to illustrate the movement of heat around the ocean. Have them identify the equator and, using two different colors (one for warm water and a second for cold).
- Draw or display the following graphic of the global conveyor belt.
- After fielding answers, introduce your students to an Educational Passages mini-boat, either in person or in an image. Mini-boats are launched into global ocean currents and transmit their position to the EP passages website twice a day, using the following URL: http://educationalpassages.com/active-boat-map/.
- Project the active boat map on your board. Ask them to evaluate their predictions.

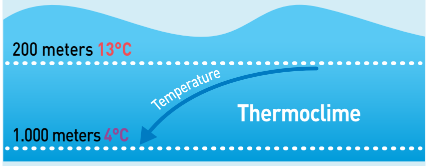


Figure 1. Example of a possible graphic

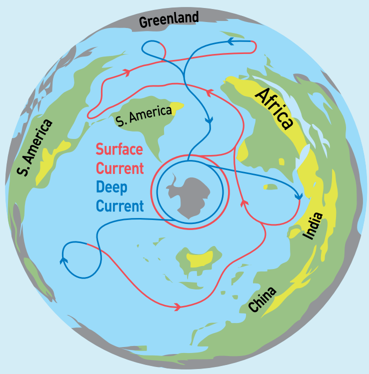


Figure 2. Example of a global coveyor belt.

Teaching tips and strategies, including eventually discussion questions

- How can we evaluate the accuracy of the map?
- If you have access to a mini-boat, where do you think the boat should be launched?
- What can we gain from launching a mini-boat?

Assessment Strategies, and learning outcomes defined

Evaluation is based on their final product as well their discussion and ability express themselves. Furthermore, it should be based on their understanding on the role of the ocean current and temperature's effect on water flow.

Additional suggestions for conducting the activity with younger and/or older audiences and in a non-formal setting

- **Younger students**
  Prefer audio/visuals formats and use the educational passages website
- **Older students**
  Propose a collaborative activity with a production of a boat
- **Non-formal settings**
  Organize an ocean related sailing club

Additional resources, e.g., websites, printed material, software, data sets, etc.

http://educationalpassages.com/
http://educationalpassages.com/active-boat-map/

References used to develop the activity

Modeling Thermohaline Water Flow." *Exploring Our Fluid Earth*. Curriculum Research & Development Group, University of Hawaii: 2017. <http://bit.ly/2q2BTTR>

2.1.5 Build a buoy

Build a buoy | 120-150 minutes | Douglas R. Levin | 6 -13 years

6 7

14 LIFE BELOW WATER

14.2

6 CLEAN WATER AND SANITATION

11 SUSTAINABLE CITIES AND COMMUNITIES

Focus on:

Cognitive learning objectives

I. The learner understands the buoyancy and ocean engineering approach.
II. The learner knows about opportunities for designing optimal devices.

Socio-emotional learning objectives

I. The learner is able to demonstrate the understanding of an object's center of gravity and buoyancy.
II. The learner is able to design & build a buoyant buoy.
III. The learner is able to differentiate between a channel marker and basic observation buoy.

Focus on, with reference to the UNESCO Education for Sustainable Development (ESD) multi-perspective approach

- **The scientific perspective**
- **The sustainability perspective**

Driving questions

What challenges do engineers face when designing devices for ocean use?

How can a payload be maximized on a buoyant device?

Introduction or background information/ content necessary for teachers to conduct the activity

The following list includes the materials needed per team. This activity is designed to have students competing and recommends you acquire multiple sets of these materials to accommodate competition. On average, a group of 30 students, working in 10 teams requires:

A list of necessary materials and included attachment to conduct activity, e.g., Student Instruction Sheet(s), Diagrams, Maps, Tables, Data Sets, etc.

- PVC Pipes:
  Bucket (50mm X 160mm) PVC Pipe (150 individual pieces)
  Bucket of (50mm) 90° Elbows and Ts (100 individual pieces)
  Bucket each of 20mm 3-way, 4-way, elbows, and T-connectors (125 individual pieces)
  (spray painted individual colors for differentiation)
  Bucket of 20mm by 160mm PVC Pipe, drilled with drainage hole
  (200 individual pieces)
- (50-75) Plastic Discs (Frisbees) with four 20mm holes drilled at edge
- 150 (30cm) Reusable Plastic Cable Ties
- 300-400 Golf balls

OTHER MATERIALS:

- Scissors or snips
- 2-3 Baby pools
- 10 Indoor/outdoor thermometers
- A premade 'decoy buoy'
- 2 Rubber mallets (for getting stuck pvc apart)

2 2.1.5 Build a buoy

Steps the students will need to complete

Materials: twelve 20 mm by 160 mm PVC pipes (see Materials Overview for mm), eight 20 mm 3-way connectors, twelve 50 mm by 160 mm PVC pipes, four 50 mm 90° elbows, plastic disc with four 50 mm holes, cable ties

Create a "Decoy Buoy" using the following diagram (**Figure 3**).
*The "Decoy Buoy" is a three-dimensional cube of 20 mm PVC, mounted with zip ties to a square base of 50 mm PVC with 4 elbows with the payload disc on the top of the model. The Decoy Buoy should be left to the side, not discussed or mentioned.

*The "Working Buoy" is an example of a functional model, for teacher use only- DO NOT BUILD!! Students should not be encouraged to copy any models- correct or incorrect, they should be instructed to design, build and test a buoy of their own.

Have all materials on display to engage students as they approach activity site.

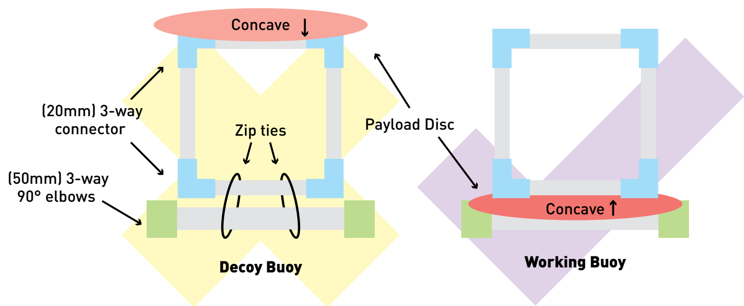


Figure 3. A "Decoy Buoy" and a "Working Buoy"

Teaching tips and strategies, including eventually discussion questions

Inquiry-based Context Setting:
With the materials displayed, ask students, "What do you think we are doing today?" Then ask, "What are buoys? And what types of buoys are there? Why are buoys in the water?"

Basic Criteria:
1. Buoys must float.
2. They must hold a payload (golf balls).
3. Buoys must be visible from the water.

Follow these steps to complete this lesson's exploration phase.
1. Divide the students into pairs or teams of three.

2. Teams choose their PVC pipes, pre-cut plastic discs, and plastic cable ties, design and construct a buoy, following the criteria provided using the engineering design process.

3. At any time during the process, students are encouraged to 'test' their model by adding the golf ball payload to their design, in the pools. Expect students to improve upon their design until they set the world record.

Further considerations:
- Depending on pool depth, the buoy design may not be able to "break the record" without touching the bottom of the pool. THE BUOY MUST FLOAT- (not positively buoyant), but may not touch the bottom of the pool when adding golf balls.

2.1.5 Build a buoy

- Buoy MUST fit inside of the pool.
- PVC pieces with holes drilled in them do not float—so do not contribute to buoyance when submerged.
- Flotation/Buoyancy can be calculated using the base.
- Right angle elbow pieces (50 mm PVC) can be turned downward into the water and do not need to be capped to contribute to flotation.
- 160 mm PVC (50 mm) can be used as a "snorkel" and to provide height in flat buoy designs.

When all teams create a successful designs, gather groups in a circle with buoys displayed

Density and Buoyancy
Constructing Explanations and Designing Solutions: Ask your students why some buoys float and others do not. Ask, "Did your final product match your original design?" Have each team share the modifications and changes they made to improve their buoy design.
Then review the following terms: density, buoyancy, and center of gravity.
Following Explanations - have students break down all of the buoys and clean up all of the materials.

Basic Observation Buoys
Convert marking buoy into a basic observation buoy. Distribute the indoor/outdoor thermometers and instruct the teams to create a basic observation buoy (BOB) that measures the temperature of the water and air. Record data.
Knowledge Activation: Ask, "Why would we want to measure the temperature of the air and water?" And, "If the temperatures are different, why are they not the same?"
Note: Do not get the thermometers wet.

Our Environmental Impact
Context Setting for Action Plan: Distribute pieces of paper and instruct students to design a buoy, equipped with different sensors that can be used to measure water quality and air quality. Ask students, "How much do these sensors cost? How will your buoy be powered? And how will you access the data it collects?"

Establish the connection between buoy data, land use, and changes in water quality. Guide learners into thinking about their role in ecosystem wellness.

Assessment Strategies, and learning outcomes defined

How to evaluate the Engineering Process.
Crosscutting Concept: "How does the structure of a buoy impact its function?"
Have students return to their original design and evaluate, either through descriptions or drawings, the changes they made and the challenges they faced.

Additional suggestions for conducting the activity with younger and/or older audiences and in a non-formal setting

Assign costs to the pieces of PVC and cable ties. Have your students calculate the total cost of their buoy (including any cable ties used) and share the costs and results with the class.

Additional resources, e.g., websites, printed material, software, data sets, etc.

- Chester River Watershed Observatory: http://www.crwo.org/
- CBIBS Website: https://buoybay.noaa.gov/
- MARACOOS/ IOOS: Integrated Ocean Observing System: https://ioos.noaa.gov/

References used to develop the activity

None

2 2.1.6 How does ocean acidification occur?

How does Ocean Acidification occur?

45 minutes

CIIMAR - Interdisciplinary Centre of Marine and Environmental

9 - 13 years old

2 **3** **4** **6**

14 LIFE BELOW WATER

14.3

4 QUALITY EDUCATION

13 CLIMATE ACTION

Focus on:

Cognitive learning objectives

I. The learner understands the ocean acidification.
II. The learner knows about the relationship between ocean and climate.

Socio-emotional learning objectives

I. The learner is able to argue for ocean acidification as a problem in relation to the climate change issue.
II. The learner is able to perceive the human connection between ocean acidification, climate change and human health.

Behavioral learning objectives

I. The learner is able to express the personal relationship with the sea.
II. The learner is able to communicate about the ocean in a meaningful way.

Focus on, with reference to the UNESCO Education for Sustainable Development (ESD) multi-perspective approach

- **The scientific perspective**
- **The historical perspective**
- **The gender equality perspective**
- **The sustainability perspective**

Introduction or background information/ content necessary for teachers to conduct the activity

The ocean absorbs a relevant part of the carbon dioxide (CO_2) that is released into the atmosphere, including that produced by human activities. The ocean therefore plays a key role in minimizing the impact of this greenhouse gases on the climate. However, as it dissolves in water, carbon dioxide results in the production of carbonic acid that causes the water to become acidic. Since the Industrial Revolution, the release of CO_2 into the atmosphere has significantly increased, particularly in the last few decades, resulting in considerable acidification of the ocean. This increase in acidity impacts marine organisms. For example, it decreases the ability of organisms like microalgae, mollusks, crustaceans and corals to build their shells, carapaces and calcium carbonate skeletons, and can also impact the physiology and reproduction of some organisms. These impacts can in turn have ecological implications, affecting marine food chains and biodiversity, as well as economic implications causing serious losses to the fishing industry. The activity introduces students to the topic by allowing them to simulate and visualize the process of acidification by dissolution of carbon dioxide into the water. Students will also observe erosion of the calcium carbonate present in skeletons and shells of marine organisms through its reaction with an acidic liquid solution.

2.1.6 How does ocean acidification occur?

A list of necessary materials and included attachments to conduct activity, e.g., Student Instruction Sheet(s), Diagrams, Maps, Tables, Data Sets, etc.

- Red cabbage extract (Cut the red cabbage into small pieces and boil it. Sieve the cabbage and collect the purple water, use it to do this activity).
- pH tape and colour chart.
- Baking soda.
- Vinegar.
- Distilled water.
- Marine shells.
- Three small plastic water bottles (two 300 ml, another 500 ml).
- Plastic straws or any other flexible tube.
- Plasticine.
- Glass cups or beakers.
- Lemon juice.

Steps the students will need to know to complete activity

A. Acidification of water induced by dissolution of CO_2

Experiment 1

1. Make a hole in the lids of each plastic bottle and connect the two bottles by passing a straw through the holes you made. Use the plasticine to seal the holes (make sure the bottles are well sealed so that exchanges of gas occur only through the straw) (**Figure 4**).

2. Add 30 ml of red cabbage water plus 60 ml of distilled water to each small plastic bottle and close them with the respective lid.

3. Add 100 ml of vinegar to the bigger plastic bottle plus one teaspoon of baking soda and immediately close it with the lid. The acetic acid of the vinegar will react with the baking soda releasing CO_2 (chemical reaction: $CH_3COOH + NaHCO_3 \rightarrow CH_3COONa + H_2O + CO_2(g)$). The CO_2 will diffuse through the straw to the smaller bottle lowering the pH of the solution.

4. Observe the color changes that occur in the smaller bottle connected to the vinegar bottle. Compare them to the other smaller bottle (containing just the red cabbage water) and use the pH tape indicator to monitor pH. Shake the bottle if needed. Compare the colors obtained with the pH color chart. Make note of the changes observed and the pH of each solution.

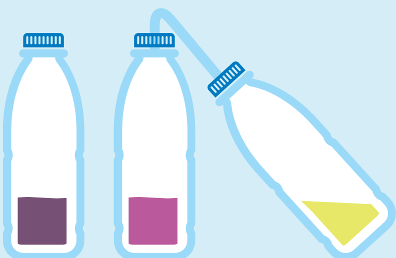


Figure 4. Example of the setup of experiment 1

Experiment 2

1. Add equal volumes of red cabbage water (15 ml) and distilled water (30 ml) to each of two glass containers or beakers.

2. Use a plastic straw to blow for about 30 s to 60 s on the test liquid of one of the beakers, creating small bubbles in the solution. Compare the changes in color obtained with the liquid of the other beaker and with the pH tape color chart. Make a note of the observations and pH.

B. Effects of ocean acidification on the shells of marine organisms

Experiment 3

1. Add 15 ml of red cabbage water and 30 ml of lemon juice to a glass or beaker. Note: the resulting solution should be red (pH<3).

2. Add 15 ml of red cabbage water and 30 ml of lemon juice to another glass or beaker.

3. Place a shell in each of the glasses and observe the release of CO_2.

2 2.1.6 How does ocean acidification occur?

Teaching tips and strategies, including discussion questions and answers

Start the activity by discussing ocean acidification with the students (what is it, what causes it) to assess previous students' knowledge on the topic.

An Experiment Log can be created with the following items/ questions to help students reflect on the topic and assess their learning

- Indicate the hypothesis tested in each experiment.
- Indicate the color changes and respective pH observed in experiments 1 and 2.
- What was the origin of the CO_2 causing acidification in experiment 2?
- Indicate the role, in your experimental design, of the second small bottle in experiment 1, and the beaker containing red cabbage water and tap water in experiment 3.
- In experiment 3, in which glass did you observe the biggest release of CO_2 (Effects of ocean acidification on the shells of marine organisms)?
- Name three human activities that cause intense release of CO_2 into the atmosphere, which contributes to ocean acidification. Can you suggest alternatives to their use?
- Name three marine organisms that suffer from the negative effects of ocean acidification.

Assessment Strategies, and learning outcomes defined

This activity introduces students to the greenhouse gas effect demonstrating experimentally ocean acidification caused by the increase of carbon dioxide in the atmosphere. Through different hands-on activities, students are expected to improve their understanding on the chemical reaction leading to ocean acidification (adjusted to their grade/age), negative impact of acidification on marine organisms, different sources of carbon dioxide emissions, how to avoid them and protect the ocean, how human activities can impact the ocean to a great extent, and increase their emotional link with the ocean.

Additional suggestions for conducting the activity with younger and/or older audiences and in a non-formal setting

An acid/base color scale prepared with red cabbage water and different volumes of vinegar or baking soda may be used to investigate pH changes with lower grade students. Students can prepare the aforementioned scale previously by mixing different volumes of vinegar or baking soda with equal amounts of red cabbage water (**Figure 5**).
Students can prepare several testing (acid solution) and control (neutral solution) beakers as in experiment 3, and leave shells of the same species and similar size immersed on the test solutions for different number of days. Each day they should remove some control and test shells and compare their resistance with crushing and crushing patterns.

Figure 5. Acid/base (pH color scale): red, pH<3; rose/violet, pH=4-5; blue, pH=6-8; green, pH=9-10; yellow, pH>11.

Additional resources, e.g., websites, printed material, software, data sets, etc.

http://www.ciimar.up.pt/

References used to develop the activity

This experimental protocol was developed by CIIMAR researchers, based on their expertise and is under a Creative Commons License for free distribution (CC; by, nc, nd). Support to its implementation can be obtained through email (ociimarnaescola@ciimar.up.pt). Additional information about the ocean acidification is made available by the Intergovernmental Oceanographic Commission of the UNESCO https://goo.gl/Wu2f7Y

The teacher strategy section should include questions that will allow the teacher to assess student prior knowledge

2.1.7 Let's go fishing

Let's go fishing | **1 hour** | **CIIMAR - Interdisciplinary Centre of Marine and Environmental Research** | **9 to 13 years old**

1 **5** **6**

14 LIFE BELOW WATER

14.3

4 QUALITY EDUCATION

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

Focus on:

Cognitive learning objectives

I. The learner understands the importance of a sustainable fishing activity.
II. The learner knows about opportunities for the sustainable use of living marine resources.

Socio-emotional learning objectives

I. The learner is able to argue for the importance of the fishing activity for cultural management.
II. The learner is able to empathize with people with a different culture approach for marine resources use.

Behavioral learning objectives

I. The learner is able to express the personal relationship with the sea.
II. The learner is able to communicate about the fishing activity in a meaningful way.

Focus on, with reference to the UNESCO Education for Sustainable Development (ESD) multi-perspective approach

- **The scientific perspective**
- **The historical perspective**
- **The gender equality perspective**
- **The cultural perspective**
- **The sustainability perspective**

Introduction or background information/content necessary for teachers to conduct the activity

Over the years' human fish consumption has led to overfishing of many fish stocks to near extinction. These circumstances highlighted the need to adopt sustainable fishing practices that will secure the preservation of biodiversity and fish populations for future generations.

Sustainable fishing practices allow the inclusion of a variety of fish species in human diets without threatening the health of fish stocks. Fisheries legislation and regulation allow humans to maintain healthy fish populations while minimizing the potential impact of overfishing on ecosystems, by for example, minimizing effects on predator-prey relationships, habitat degradation and by-catch. These policy measures oversee all aspects of the industry from fisheries to consumers. International organizations work together to set annual fishing quotas that are continuously regulated both at sea and on land.

Through hands-on experimental work, this activity will promote understanding about the consequences of unregulated fishery on natural populations targeted for human consumption. It demonstrates the importance of sustainable management and conservation practices to protect fish populations. Taking in consideration principles of fish growth, development and reproduction, students can also propose by themselves the most important regulatory fishing measures or restrictions.

2 2.1.7 Let's go fishing

A list of necessary materials and included attachment to conduct activity, e.g., Student Instruction Sheet(s), Diagrams, Maps, Tables, Data Sets, etc.

- Two aquaria bowls with polystyrene balls (that are fit for use in the food industry) or another media to resemble the ocean.
- Seafood-shaped jelly sweets (big and small of different colors) representing populations of fish targeted for human consumption (fish, octopus, shellfish) and their life-cycle stages (juveniles, adults, animals in the reproductive season).
- A small aquarium fish net.

Steps the students will need to know to complete activity

- Label both bowls (e.g. Aquarium 1 and Aquarium 2).
- Prepare two identical portions of jelly sweets. Each portion should include an equal number of small and big sweets of the same color, simulating juvenile and adult seafood populations, respectively, and some animals in their reproductive season (more vivid colors).
- Count and make a note of the number of sweets in each portion.
- Add a portion of sweets to each of the previously labelled aquaria.
- Ask the students to go fishing in Aquarium 1, using the net. Set no restrictions and allow the students to eat the sweets caught.
- Make a note of the number and types of sweets caught from Aquarium 1.
- Discuss with the students the effects of fishing with no restrictions, including reflection on what fish will be available to eat the next day, impact on populations and biodiversity. Ask students to suggest possible measures that could be implemented to avoid these effects, discussing their suggestions.
- Make a note of the restrictions decided by the group to be implemented when fishing in Aquarium 2 (e.g. size quotas, reproduction season, size of fishing net to be used, etc). Allow the students to implement the measures discussed when fishing in Aquarium 2.
- Let the students go fishing in Aquarium 2 following the restrictions agreed by the group. Remember them to return to the bowl any fish caught that do not meet the criteria decided.
- Make a note of the number and types of sweets caught in Aquarium 2.

Teaching tips and strategies, including discussion questions and answers

The activity should begin with a discussion with the learners about seafood as an invaluable ocean resource to human kind, fisheries, their need, impact and management. This will allow them to assess previous knowledge of the students about the topic.

An Experiment Log can be created with the following items/questions to help students reflect about the subject and assess their learning:

- Indicate the hypothesis to be tested in this experiment.
- For each species and life-cycle stage (juveniles, adults, breeding adults), indicate how many animals (sweets) were caught from Aquarium 1 and 2.
- Build a percentage graph for the classes and values registered. Include labels for each axis and a legend for the graph.
- What happened in the aquarium where unregulated fishing was allowed?
- What can you conclude about the need (or not) to implement fishing restrictions?
- Which stages in the life-cycle represent a preservation priority in order to sustainably manage fisheries?
- What measures were agreed for implementation when fishing in Aquarium 2?
- What are the ecosystem problems or effects caused by trawl fishing?

2.1.7 Let's go fishing

2

Assessment Strategies, and learning outcomes defined

Unregulated fishing can easily lead to extinction of populations, which in turn results in loss of biodiversity and consequently less seafood species available for human consumption. The main regulations learners should consider for implementation during the activity are:

- The need to preserve juveniles (smaller sweets) by implementing a minimum size guide for specimens caught (age/length correlation according to the species life cycle).
- The life cycle, i.e. fishing should not occur during the breeding season. The bigger sweets of more vivid colors can be used to simulate animals in their breeding season.
- Adequate sized mesh for fishing nets (adapted to each species).

Additional suggestions for conducting the activity with younger and/or older audiences and in a non-formal setting

Suggestion: Fishing should be more difficult in Aquarium 2. Discuss with the students the need to employ different nets and techniques that are more suitable for different species (pelagic vs benthic species, trawl fishing and sea-floor integrity or sediment remobilisation) and size quotas in place.

Additional resources, e.g., websites, printed material, software, data sets, etc.

https://www.ciimar.up.pt

References used to develop the activity

The activity was developed by CIIMAR researchers, based on their expertise and is under a Creative Commons License for free distribution. Additional information about the topic is available at the Fisheries and Aquaculture Department of the Food and Agriculture Organization of the United Nations (http://www.fao.org/fishery/en).

The teacher strategy section should include questions that will allow the teacher to assess student prior knowledge

https://www.ciimar.up.pt

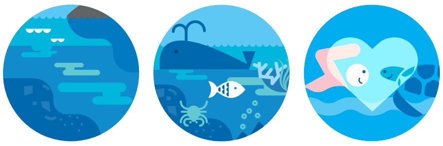
2 2.1.8 Integrated Multi-Trophic Aquaculture - IMTA

Integrated Multi-Trophic Aquaculture - IMTA

120 minutes

CIIMAR - Interdisciplinary Centre of Marine and Environmental Research

+ 12 years



1 **5** **6**

14.1

Focus on:

Cognitive learning objectives

I. The learner understands the connection of marine ecosystems to the sea and the life it holds.
II. The learner knows about opportunities for the sustainable use of living marine resources according to different ecological point of view.

Socio-emotional learning objectives

I. The learner is able to argue for the importance of the aquaculture for a sustainable management.

Behavioral learning objectives

I. The learner is able to express the personal relationship with the aquaculture and new way to use marine ecosystem services.
II. The learner is able to communicate about the ocean in a meaningful way.

Focus on, with reference to the UNESCO Education for Sustainable Development (ESD) multi-perspective approach

- **The scientific perspective**
- **The historical perspective**
- **The gender equality perspective**
- **The value perspective**
- **The sustainability perspective**

Introduction or background information/ content necessary for teachers to conduct the activity

Intensive animal aquaculture releases high amounts of nutrients into aquatic ecosystems. This is due to the fact that only part of the feed supplied is retained by the species cultivated. The high percentage of organic matter and inorganic nutrients released can cause eutrophication of coastal areas and other aquatic systems. Integrated multi-trophic aquaculture (IMTA) systems use species of different trophic levels in order to reduce waste while increasing total productivity. IMTA is the practice of combining the cultivation of fish or shrimp species with the culture of species extracting the organic matter (i.e. which feed on organic particles, such as faeces and food debris) and the inorganic part (*i.e.* using the inorganic nutrients dissolved in water) resulting from the former. Mussels, oysters, clams, sea urchins or polychaetes are some of the most widely used organisms to remove particulate organic matter. Macroalgae (e.g. *Ulva, Gracilaria, Saccharina, Laminaria*) are the organisms typically used to filter the inorganic nutrients. Thus, when integrated with aquaculture of fish or shrimp, extractive organisms allow transforming wastes into productive resources. In this way, the wastes of intensive animal aquaculture are valued as resource rather than considered a burden or pollution. IMTA allows the creation of balanced systems with environmental sustainability, favoring economic diversification (through product diversification, which brings company stability through risk reduction) and social acceptability (due to the use of best management practices).

2.1.8 Integrated Multi-Trophic Aquaculture - IMTA

This activity will allow students to build a small IMTA system as nature-based solution for the sustainable exploitation of marine resources, minimizing impact on the environment and fostering economic valuation through the diversification of products. In this hands-on experiment, students will build a small IMTA having the opportunity to discuss important ecological concepts at the base of these systems, advantages of this integrated solution over traditional aquaculture, advantages of aquaculture products over fisheries sea-food. With the necessary complexity adjustment, this protocol can be used with students from elementary to high-school levels.

A list of necessary materials and included attachment to conduct activity, e.g., Student Instruction Sheet(s), Diagrams, Maps, Tables, Data Sets, etc.

- Four 5l capacity aquaria
- Air pumps
- A water pump
- Saltwater fish
- Saltwater filter feeders (e.g. mussels, oysters, clams, sea-urchins, polychaetes)
- Seaweeds (e.g. *Ulva, Gracilaria, Saccharina, Laminaria*)
- Silicone tubes
- Aquarium taps
- Seawater (artificial seawater may be used)
- Water thermometer
- Simple aquarium kits to measure pH and nutrient (ammonia, nitrates, nitrites, phosphates)

Steps the students will need to know to complete activity

- Assemble the IMTA (**Figure 6**).
- Aquaria need to be placed on uneven levels so that water can circulate successively from the first (fish or shrimp) to the second aquarium (filter feeders) and from the second to the third (seaweeds) one.
- The fourth aquarium will serve as storage tank.
- The water pump should be placed here to allow recirculation of the water arriving from the seaweeds tank back to the first aquarium.
- Fill the aquaria with seawater and turn on the pump to start water circulation. Place an air pump on each aquarium.
- Place the fish in the first aquarium (biomass density of 10 kg/m^3).
- Place the filter feeders in the second aquarium (biomass density of 25 kg/m^3).
- Place the seaweeds in the third aquarium (biomass density of 10 kg/m^3).
- Turn off the water pump to stop the flow of water between the different aquariums and measure temperature, pH and nutrients with the aquarium kits (according to manufacturer instructions). Take this as time zero of your measurements. Repeat the measurements every 30 minutes. Record the values on the Experiment Log sheet.
- After 90 min switch on the water pump (time zero) and take measurements every 30 min for two hours.

Figure 6. CIIMAR integrated multi-trophic aquaculture kit. A video showing the assembling is available at www.ciimar.up.pt/oCIIMARnaEscolaOCEANLAB.php

Teaching tips and strategies, including discussion questions and answers

The activity should be started with a discussion with the students on their perception about aquaculture and important ecological concepts such as fish stocks, food chain, eutrophication, biodiversity. This will allow assessing their previous knowledge about the topic.

2 2.1.8 Integrated Multi-Trophic Aquaculture - IMTA

An Experiment Log can be created with the following items/ questions to help students reflect about the subject and assess their learning

- Indicate the hypothesis to be tested in this experiment.
- Make a schematic diagram of the integrated multi-trophic aquaculture (IMTA) system that you assembled, showing all the materials used.
- Indicate the species (common and species names) you used in your IMTA as classic aquaculture species, filter feeders and inorganic filters.
- Record pH and nutrient values measured over time on a table. Make a legend to the table.
- Plot on a graph the values obtained for pH and ammonia before and after water recirculation. Write appropriate labels x and y axes and a legend for the figure you just made, as well.
- Interpret the variation of the parameters measured and propose an explanation for the differences obtained between the measurements performed before and after water recirculation.
- What is the purpose of measuring temperature?
- Indicate the advantages of IMTA over conventional aquaculture.

Assessment Strategies, and learning outcomes defined

IMTA systems are nature-based solutions linked to waste reduction, but also to circular economy. They provide product diversification while increasing both environmental and economic sustainability of aquaculture. Their social acceptability can thus be greater than that of common aquaculture. However, whilst IMTA has already been studied for some years, it is only now reaching industrial aquaculture practice. The public in general is, thus, still unfamiliar with the IMTA concept and its advantages over conventional methods. Here, there is an opportunity to increase ocean literacy and create a positive image of sustainable aquaculture by showing how such systems can reduce or eliminate some of the environmental problems while keeping economic and social benefits. With this hands-on activity students are expected to increase their knowledge about aquaculture and the advantages of aquaculture products to human nutrition and health. They should also improve their understanding about essential aspects of biodiversity, concepts of food chains, eutrophication associated with the discharge of effluents enriched in inorganic nutrients, principles of waste reduction and circular economy. Finally, the activity can contribute to open their thinking to nature as inspiration for development of sustainable solutions addressing human needs while protecting and preserving natural resources for future generations.

Additional suggestions for conducting the activity with younger and/or older audiences and in a non-formal setting

This IMTA system can be easily exhibited in science fairies or open science days and used to discuss the concept with participants and advantages of aquaculture products. If hands-on is intended, two similar IMTA systems may be prepared and placed side by side, one with fully working recirculation, the other with no recirculation. Participants can then use the aquaria kits to measure some water parameters and compare the differences.

Additional resources, e.g., websites, printed material, software, data sets, etc.

O CIIMAR na Escola: https://www.ciimar.up.pt

References used to develop the activity

The activity was developed by CIIMAR researchers, based on their expertise accumulated over years of investigation on IMTA and is under a Creative Commons License for free distribution. Additional information about the topic can be found in the "FEATURE ARTICLE – Improving the public image of aquaculture" published only by the International Council for the Exploration of the Sea (ICES, https://goo.gl/RDyxyJ).

The teacher strategy section should include questions that will allow the teacher to assess student prior knowledge

2.1.9 Let's explore the deep sea

Let's explore the deep sea

60 min

Silva, F.; Mata, B.; Conceição, P.; Costa, R.; Portuguese Ministry of the Sea - DGPM

12-18 years

7

14 LIFE BELOW WATER

14.A

4 QUALITY EDUCATION

Focus on:

Cognitive learning objectives

I. The learner becomes familiar with the scientific equipment associated with oceanographic campaigns.
II. The learner is able to recognize the morphology of the seafloor and to identify the different types of seabed resources.
III. The learner is able to understand the connection between the different morphologies of the seabed and the different geological resources.

Socio-emotional learning objectives

I. The learner can understand the importance of the resources and their applications in our daily lives.

Behavioral learning objectives

I. The learner is able to understand the importance of protecting the ocean.
II. The learner is able to make conscious decisions regarding the ocean.
III. The learner is able to correctly communicate about the ocean in a coherent and informed way.

Focus on, with reference to the UNESCO Education for Sustainable Development (ESD) multi-perspective approach

- **The scientific perspective**
- **The geographic perspective**
- **The value perspective**
- **The sustainability perspective**

Introduction or background information/content necessary for teachers to conduct the activity

The main goal of this activity is to plan an oceanographic campaign for the exploration of a marine area with non-living and living resources. Learners have a limited budget and get to understand all the logistics associated with the development of an expedition. It is a group activity, with 5-8 students per group.
It is suggested to show the different types of resources, living or non-living, that exist on the deep sea, while associating them with products that we use in our daily lives.
In the case of living resources, for example, the teacher can mention their direct application in the pharmaceutical industry (sponges and acyclovir) or in the food sector (algae and sushi), and the blue biotechnology.
In the case of non-living resources, however, they are not explored in the deep sea, but on land. But these resources are finite, and in the near future their deep-sea exploration can become a reality. Metals are used a lot in technology (mobile phones, televisions, windmill turbines, electric cars), and in medicine and pharmaceutical industry (various medicines, CAT equipment, cancer treatment).
The students should be able to realize that we know more about other planets than we know about our deep sea. If we want to be able to explore the sea in a sustainable and rational way it is necessary to know what exists at the bottom of the ocean. That's why we these oceanographic campaigns are so important.

2 2.1.9 Let's explore the deep sea

A list of necessary materials and included attachment to conduct activity, e.g., Student Instruction Sheet(s), Diagrams, Maps, Tables, Data Sets, etc.

- Cards with scientific equipment (**Figure 6a**).
- Cards with marine professions (**Figure 6b**).
- A seabed map (e.g. Atlantic Ocean or Pacific Ocean).
- Different markers for each type of resource (e.g. black stones for polymetallic nodules, green stones for sponges, white stones for polymetallic sulphides and blue stones for Fe-Mn Crust).

Introduction or background information/ content necessary for teachers to conduct the activity

First Step (for each group):

- Choose a living or non-living resource to explore;
- Locate it on the map;
- Choose the right vessel on which to travel and to transport the equipment (if necessary);
- Choose five pieces of scientific equipment that will be of use in the exploration of the chosen resource;
- Establish a multidisciplinary team with eight elements according to the campaign goal;
- Decide the length of the expedition, knowing that there's a limited budget of €300,000.

Second Step (for the whole class):

Each group presents the planning of their campaign to the whole class, justifying their choices from different perspectives (e.g. economic, scientific, geographic, environmental).

Teaching tips and strategies, including discussion questions and answers

Research the topic on the internet.
Invite a marine geologist or a scientist involved in oceanographic campaigns for a short talk with the students.

Assessment Strategies, and learning outcomes defined

The evaluation of the acquired knowledge can be done through a final presentation of the project by the students.

Additional suggestions for conducting the activity with younger and/or older audiences and in a non-formal setting

It is possible to adapt the language and concepts used in this activity to all levels of education.

Additional resources

https://ed.ted.com/lessons/deep-ocean-mysteries-and-wonders
https://ed.ted.com/lessons/on-exploring-the-oceans-robert-ballard
https://www.youtube.com/watch?v=ir4n458MV9k
http://web.vims.edu/bridge/?svr=www#
http://www.emepc.pt/en/the-rov-luso
http://www.emepc.pt/en/the-project
http://www.noaa.gov/education/education-resource-collections
https://goo.gl/Jh1Jzb

References used to develop the activity

https://www.emepc.pt/en/the-project

2.1.9 Let's explore the deep sea

OCEANOGRAPHIC VESSEL

Description
Scientific investigation vessel
Function
Deep sea geological, biological and geophysical data collection; Oceanographical data collection

IDROGRAPHIC VESSEL

Description
Scientific investigation vessel
Function
Bathimetric data collection

RESEARCH VESSEL

Description
Scientific investigation vessel
Function
Geological and biological data collection; Oceanographical data collection

CORER

Description
Sediment sampling
Function
Stratified Sediment sampling

VAN-VEEN DREDGE

Description
Sampling equipment
Function
Sediments and benthic organisms sampling

DREDGE

Description
Sampling equipment
Function
Seabed rock sampling

ROSETTE

Description
Sampling equipment
Function
Water sampling at different depth collection

CDT

Description
Oceanographic data
Function
Conductivity, temperature and depth data collection

MULTIBEAM

Description
Oceanographic data
Function
Deep sea morphological data collection. It allows mapping of the ocean floor

PLANKTON NET

Description
Oceanographic data
Function
Plankton net

NISKIN BOTTLES

Description
Sampling equipment
Function
Water sampling at different depths, for biological and chemical studies

SIDE SCAN SONAR

Description
Accoustic mapping equipment
Function
Low depth detection equipment. Allows for the detection of small objects in the seabed and water column

AUV

Description
Autonomous Underwater Vehicle
Function
Depending on the sensors added it allows for autonomous mapping, imaging or collection of other oceanographic data. It follows a pre programed rout

ROV

Description
Remotely Operated Vehicle
Function
Equipment to explore and collect geological, biological and oceanographic data

FLUID PROBE

Description
Hydrothermal fluid sampling equipment
Function
Hydrothermal fluids sampling for chemical analysis

RESEARCH SUBMERSIBLE

Description
Investigation and sampling
Function
Equipment to explore and collect geological, biological and oceanographic data, Direct observation allowed

GRAVITIC CORER

Description
Sampling equipment
Function
Stratified sediments sampling up to 30m (Calypso Corers)

GEOLOGIST	COOK	DOCTOR	ELECTRICIAN	FISHERMAN	HYDROGRAPHER	
BIOLOGIST	SCUBA DIVER	NURSE	CIVIL ENGINEER	ARCHITECT	OCEANOGRAPHER	
CHEMIST	SAILOR	GEOPHYSICIST	ELECTRICAL ENGINEER	FIREMAN	ROV PILOT	SIG's EXPERT

VESSEL COSTS
20.000€ PER DAY

VESSEL VELOCITS
10 kt
(1 knot ~ 1 nautical mile/hour)

Figure 6: Examples of cards with marine equipment (a), and with marine professions (b).

2 2.1.10 Watershed activity using anadromous fish cherry salmon to understand land - ocean connection

Watershed activity using anadromous fish cherry salmon to understand land- ocean connection

45 minutes

Tsuyoshi Sasaki

+ 7

1 **3** **4** **5** **6**

14 LIFE BELOW WATER

**14.1 , 14.2 , 14.4
14.5 , 14.6 , 14.7**

13 CLIMATE ACTION

16 PEACE, JUSTICE AND STRONG INSTITUTIONS

Focus on:

Cognitive learning objectives

I. Learner is able to understand of the healthy Forest River Ocean connection through experiences.
II. Learner is able to understand the importance of connection between the ocean and land including human being.

Socio-emotional learning objectives

I. Learner is able to understand the importance of forest, river and sea connections through experience.
II. In order for human beings to live, learner is able to understand the importance to have a healthy connection between the forest and river and the ocean.

Behavioral learning objectives

I. The learner is able to understand the connection between healthy forests and rivers and the sea, and to arise a consideration behavior in daily life.
II. In order to maintain a connection among healthy forests and rivers and the sea, the learner has the opportunity to think and act to preserve them along with their families.
III. The learner understands the scarcity of food resources born from healthy forests and river and sea environments and therefore to change consumption behaviour.

Focus on, with reference to the UNESCO Education for Sustainable Development (ESD) multi-perspective approach

- **The scientific perspective**
- **The historical perspective**
- **The geographic perspective**
- **The gender equality perspective**
- **The value perspective**
- **The cultural perspective**
- **The sustainability perspective**

Introduction or background information/ content necessary for teachers to conduct the activity

Development and implementation of the Cherry Salmon MANABI Project.
The Cherry salmon MANABI Project in Hei River has been conducted with the intention of reconstructing a local watershed community, and to forge links among researchers, educators, students, residents, fisherman, food processing companies, fishery commercial unions, and others. The education activities are implemented five times per year with emphasis on the life history from hatching larva to spawning season as follows. #1 April: Salmon released activities, #2 May: The World Cherry Salmon Summit in IWATE, #3 August, September: Collecting Aquatic Organisms and Floating in the Hei River, #4 November: Fertilization Experiment of Trout and Wonder of Cherry Salmon, #5 December: Salmon preparation labeling for release. (**Figure 7**)

2.1.10 Watershed activity using anadromous fish cherry salmon to understand land - ocean connection

2

A list of necessary materials and included attachments to conduct activity, e.g., Student Instruction Sheet(s), Diagrams, Maps, Tables, Data Sets, etc.

The program was developed to make people living in Tokyo area cultivate an interest in the natural environment along the Hei River. Miyako and Shinagawa cities chose to conduct joint projects with the Cherry salmon MANABI project. This project provided inter-communities and generations for people residing in various areas such in Ohta city, Minato city, Shinagawa city in Tokyo, and Totsuka city in Kanagawa prefecture.

Aquatic Marine Environmental Education Leader trained at Tokyo University of Marine Science and Technology will support teachers. The leaders understand ocean literacy and have the ability to teach the connection of Forest River Ocean in a familiar environment.

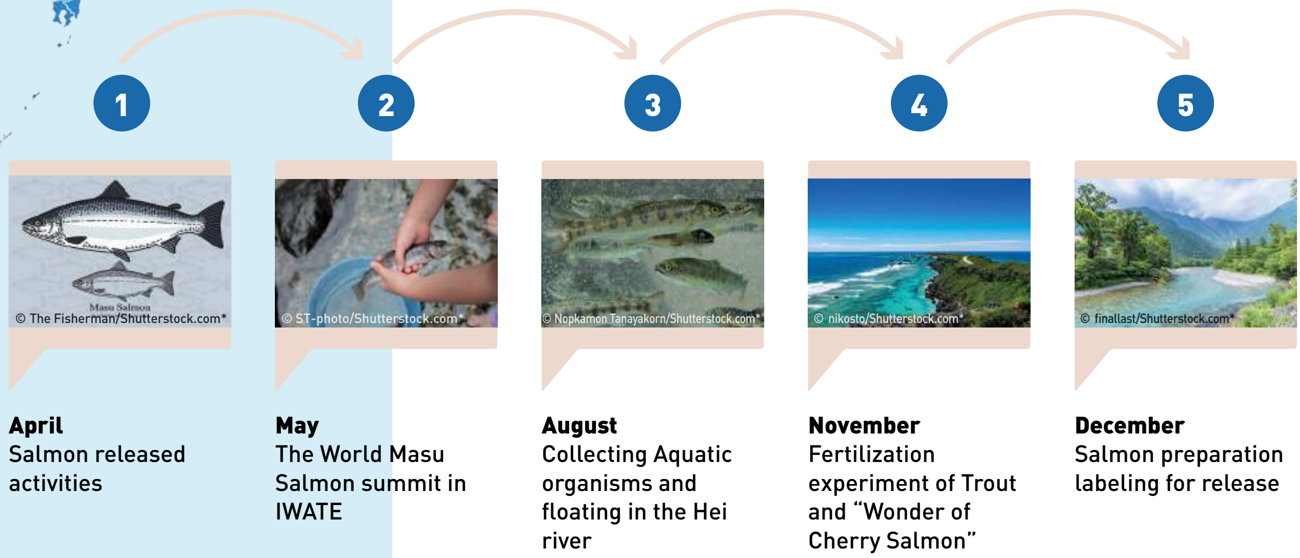


Figure 7. The education activities are implemented five times per year.

A list of necessary materials and included attachment to conduct activity, e.g., Student Instruction Sheet(s), Diagrams, Maps, Tables, Data Sets, etc.

Material: discussion board, post it, pencil, salmon, wet suits.

Steps the students will need to know to complete activity

The education activities are implemented five times per year with emphasis on the life history from hatching larva to spawning season.

Teaching tips and strategies, including discussion questions and answers

Leaning cycle theory and Aquatic marine environmental education theory.

2 2.1.10 Watershed activity using anadromous fish cherry salmon to understand land - ocean connection

A Have you looked at the river and living creatures and talked with someone about the river? (Relatedness)	**Table 1 Pre-test items of questionnaire** A1 I am always looking at the river. A2 I have experience playing in the river. A3 I have experience showing creatures I found, caught with my friends and teachers and family. A4 I have experience talking about creatures I found, caught to my friends and teachers and family. A5 I want to hear and talk about creatures.
B Have you ever engaged in river preservation? (Competence)	B1 I know many kinds of creatures living in the river. B2 I know where fish live. B3 I know many kinds of creatures can live there because the river is clean. B4 I recognized what species are alive in the river. B5 I think the Hei River is a clean river. B6 I want to protect nature. B7 I think the forest, river, and ocean are mutually connected.
C Can you engage in knowing and protecting the river? (Autonomy)	C1 I have experience with talking about creatures that live in the river. C2 I always care about the river and want to maintain water cleanliness. C3 I have experience in talking about the connection between the forest, river, and ocean.
D Free description	Please list what creatures live in the river.
Assessment Strategies, and learning outcomes defined. **A** Did you discuss it with participants? (Relatedness)	**Table 2 Post-test items of questionnaire** A1 I was able to show creatures I found to friends and teachers. A2 I was able to talk about creatures I caught with my friends and teacher. A3 I want to hear and talk about creatures.
B Were you able to learn anything with participants? (Competence)	B1 I realized that there are many creatures living in the river. B2 I realized where fish live. B3 I realized that many creatures can live in the river because of clean water. B4 I understood what species of creatures live in the river. B5 I thought Hei River is clean. B6 I want to protect the nature of the river. B7 I think that the forest, river, and ocean are connected.
C Can you tell us a little about what you learned today? (Autonomy)	C1 I want to talk about creatures in the river. C2 I want to tell people to clean up and think about more neighboring rivers. C3 I want to inform others about the connections between forests, rivers, and the ocean, and creature connections.
D Free description	What did you learn and find out in today's activity? They understand relationship between human impact and land use and watershed and ocean.
Additional suggestions for conducting the activity with younger and/or older audiences and in a non-formal setting	https://youtu.be/gNhnRs2dp_Q
Additional resources, e.g., websites, printed material, software, data sets, etc.	
References used to develop the activity	https://www.jstage.jst.go.jp/article/suisan/82/5/82_WA2321-3/_pdf

2.1.11 Eat the right fish

Eat the right fish

Costa, R., Mata, B., Silva, F. and Geraldes, D. – Portuguese Ministry of the Sea - DGPM

10+

1 **4** **6**

14.2

Focus on:

Cognitive learning objectives

I. Learner is able to understand the importance of connection between the fishing actions and human activities.

Behavioral learning objectives

I. The learner is able to understand the connection between fishing and consumption, and to arise a consideration behaviour in daily life.
II. In order to maintain a connection among healthy ocean and fishing activities, the learner has the opportunity to think and act to preserve species.
III. The learner understands the scarcity of food resources and therefore to change consumption behaviour.

Focus on, with reference to the UNESCO Education for Sustainable Development (ESD) multi-perspective approach

- **The scientific perspective**
- **The sustainability perspective**

Introduction or background information/ content necessary for teachers to conduct the activity

The ocean supports a huge diversity of life and ecosystems. Each species has its own function, and its presence is essential for the proper functioning of the oceanic communities. By intervening in these communities, either through fishing or other economic activities, man causes an alteration that is often harmful to the whole ocean.

A list of necessary materials and included attachment to conduct activity, e.g., Student Instruction Sheet(s), Diagrams, Maps, Tables, Data Sets, etc.

Materials:

- Camera/smartphone
- Computer
- Cardboard
- Notebook
- Pencil
- Yarn
- Scissors

Steps the students will need to know to complete activity

The followings sections present three distinct activities all dealing with issue related to sustainable fish consumption.

2

2.1.11 Eat the right fish

Fish size matters
Activity 1

90 min

- Search on the Internet for pictures of fish that can be caught, and for pictures of endangered species whose fishing should be avoided.
- Print a picture of each fish (with about 10/15 cm) and crop it.
- Place all the cardboard fish in a black bag. Ask each student to draw a fish from the bag.
- The whole class should then analyze each drawn fish and decide whether it should be fished or not, and what are its characteristics, habitat, food, etc.
- The option of whether or not to catch the fish can be based on the website Fish Size Matters: http://fishsizematters.eu.

Eat the right fish
Activity 2

180 min

- Visit different places selling fish (market, supermarket, wholesale fish market).
- Take a survey among fish vendors to record which species sell more, and which sell less. Try to understand if these species were caught or farmed.
- Take a survey to other classes or to the students' parents in order to list the most consumed species and their origin.
- Investigate whether the consumed species are endangered.
- Compare the results of both surveys.
- Create identification plates for each species, similar to the ones used at fish outlets. In addition to the usual information, these plates must mention each species conservation status.
- Prepare a quick marine species consumption guide, stating information on which species to consume and which to avoid.
- Advertise the aforementioned consumption guide of marine species in schools, public agencies, to families, etc.
- Promote the survey data and the findings of the activity on the school's website / social media.

Being a fisherman
Activity 3

90 min

- Investigate the food chain of some marine species.
- Assign a species to each student.
- Connect the prey to its predator using a string.
- Elect one student as a fisherman. He is equipped with a fishing rod (scissors).
- Remove the species that suffer from overfishing (the "fisherman" will cut the string that connects the removed species to its predators).
- Record what happens when some species are removed.

Assessment Strategies, and learning outcomes defined

- Get to know more about the ocean that surrounds us.
- Recognize the causes that have led to the extinction of marine species.

Additional suggestions for conducting the activity with younger and/or older audiences and in a non-formal setting

Additional resources, e.g., websites, printed material, software, data sets, etc.

https://www.youtube.com/watch?v=YACTNvuijQY

References used to develop the activity

None

2.1.12 How deep is the sea?

How deep is the sea? | **60 min + 2-4 h lab** | **Francesca Alvisi** | **11+**

1 2 3 4 5 6 7

14.A, 14.C

Focus on:

Cognitive learning objectives

I. The learner is aware of the different shape of seas and oceans and their origins.
II. The learner understands the need of different management approach to different spatial context of maritime zones.
III. The learner understands better the connection between land and sea and the influence of humans on the marine environment and the life it holds, including the high seas' role as a provider of food, and their economic value.

Socio-emotional learning objectives

I. The learner is able to understand/accept the natural complexity.
II. The learner is able to influence groups that engage in unsustainable use of high seas ocean resources.
III. The learner is able to empathize with people with a different culture approach for marine resources use.

Behavioral learning objectives

I. The learner is able to research their country's (inter)dependence on the sea.
II. The learner is able to share knowledge and experience with their representatives to discuss about marine issues.
III. The learner is able to raise awareness on marine issues in the local community.

Focus on, with reference to the UNESCO Education for Sustainable Development (ESD) multi-perspective approach

- **The scientific perspective**
- **The historical perspective**
- **The geographic perspective**
- **The human rights perspective**
- **The cultural perspective**
- **The sustainability perspective**

Introduction or background information/ content necessary for teachers to conduct the activity

This activity could be well developed with teachers from different disciplines i.e. geography, science, history, biology, civics, economy.
They will need some knowledge of basic cartographic principles and some skill/ contact to find topographic/bathymetric maps online to use in the lab.
Watch this video by GEBCO (General Bathymetric Chart of The Oceans) to focus on the topic: https://www.youtube.com/watch?v=A-zliM6uAzE

2 2.1.12 How deep is the sea?

A list of necessary materials and included attachment to conduct activity, e.g., Student Instruction Sheet(s), Diagrams, Maps, Tables, Data Sets, etc.	▪ Material: a pen/pencil, a topo/bathymetric map of a marine area (2 copies), glue for paper, scissors, recycled cardboard sheets (enough sheets to complete the 3D model), colors for paper (e.g. brown, blue, white, black), toilet or kitchen paper. ▪ How to make a 3D map: https://www.youtube.com/watch?v=AZ7lWrqidgk ▪ Site analysis 3D model: https://www.youtube.com/watch?v=j6BQ3VZt_tE
Steps the students will need to complete	▪ Watch introductory videos and tutorials. ▪ Navigate with Google Earth or similar to investigate ocean and marine basins settings. ▪ Discuss in the classroom which oceanic or marine basins to represent with the 3D sketch model, why and how (vertical and horizontal scales, themes, etc.). ▪ Get the bathymetric map of the chosen basin and print it in two copies (only 1 paper or more if needed). ▪ Define working groups in charge of building the 3D model (each group will contribute for a piece of the model or a part of the job). ▪ Within each group, each student will choose his/her own role (designer, cutter, tracer, assembler, finisher, etc.). ▪ After building the model they will add the themes and legenda, etc. ▪ They will present their results in public events such as school days, science festival, local community celebration, etc.
Teaching tips and strategies, including eventually discussion questions	▪ Navigate and observe the different setting of oceanic and marine basins. ▪ Try to explain why they are different (geomorphology, geology, geographic. location, marine resources, threads, etc.) and how (shape, depth, relationship with the continents, etc.). ▪ Make sure that students choose on the base of an interest and not by chance. ▪ Circulate their decision and position papers within the classroom and discuss them. ▪ Make sure students get to the final realization of the 3D model and related information.
Assessment Strategies, and learning outcomes defined	▪ **Younger students** Reduce the complexity of the basin to be represented (i.e. smaller area, simplified isobaths, few layers, use different materials such as paper or clay, etc.). Choose an example close to home (even a lake basin). ▪ **Older students** Deepen the study of the basin characteristics, its marine resources, uses and management, to produce a raise in the awareness on the link between shape and characteristics. ▪ **Non-formal settings** This activity can be used as a lab during public events, even with a former preparation of the different layers to be used as a 3D puzzle.
Additional resources, e.g., websites, printed material, software, data sets, etc.	▪ Introduction to Topographic Maps: https://www.youtube.com/watch?v=zqPMYGDxCr0 ▪ Understanding Topographic Maps: https://www.youtube.com/watch?v=L1AWNR-Y0pQ ▪ Visualizing Contour (Topographic) Maps In Google Earth: https://www.youtube.com/watch?v=55BNufFfXdc ▪ Global Seafloor Update in Google Earth: https://www.youtube.com/watch?v=_NBFjVY6kKc ▪ Google Earth Bathymetry and Nautical Charts: https://www.youtube.com/watch?v=P8T4KiRSV-M

2.1.12 How deep is the sea?

References used to develop the activity

- Introduction to Topographic Maps: https://www.youtube.com/watch?v=zqPMYGDxCr0
- Understanding Topographic Maps: https://www.youtube.com/watch?v=L1AWNR-Y0pQ
- Visualizing Contour (Topographic) Maps In Google Earth: https://www.youtube.com/watch?v=55BNufFfXdc
- Global Seafloor Update in Google Earth: https://www.youtube.com/watch?v=_NBFjVY6kKc
- Google Earth Bathymetry and Nautical Charts: https://www.youtube.com/watch?v=P8T4KiRSV-M

2 2.1.13 The sea: water that... sustains us!

The sea: water that...sustain us!

120 minutes or lessons
(could be divided into three parts by two hours each.)

Silvia Merlino, Rosaria Evangelista, Carlo Mantovani, Marinella Abbate, Marco Bianucci.

from 9 to 14 years

1 **3** **4** **5** **6**

14 LIFE BELOW WATER

14.A

4 QUALITY EDUCATION

Focus on:

Cognitive learning objectives

I. The learner is aware of the chemical composition of the seawater.
II. The learner understands better the connection between land and sea and the influence of humans on the marine ecosystems and the life it holds.

Socio-emotional learning objectives

I. The learner is able to understand/accept the natural complexity.
II. The learner is able to influence groups that engage in unsustainable use of high seas ocean resources.

Focus on, with reference to the UNESCO Education for Sustainable Development (ESD) multi-perspective approach

- **The scientific perspective**
- **The sustainability perspective**

Introduction or background information/ content necessary for teachers to conduct the activity

Scientific overview
This didactic paths deal with chemical and physical water sea properties, and how they have influence on ocean circulation, world climate and biosphere. Background information to be taught:

Structure of the water molecule, the concept of chemical bond and, in particular, of the "hydrogen bond"; concept of "polarity" of a chemical bond; Archimede' low and buoyancy; concepts of *specific weigh* and *density*; chemical structure of salt NaCl; concept of ions and of "*crystalline structure*"; concept of "salinity" and "temperature", and how they influence the water density; basic knowledge of phytoplankton and know what the "thermoaline current" is.
Teaching these physics and chemistry concepts in primary and lower secondary schools involves the choice of particular strategies and methodologies, as students at these educational stages lack the mathematical tools needed to formalize concepts. Furthermore, in many cases they lack the basic knowledge of many phenomena, the interest in direct observation and experimentation, and the desire to participate in the laboratory activity. Very often, they have an intuitive and misleading interpretation of some concepts, which causes distortions in the learning process, and are difficult to get rid of. A relevant example is the physical concept of specific weight, which is regularly confused with the weight, and this last one is often confused with mass. The concept of specific weight (or density) is unintuitive and should be introduced in an appropriate way, not as an a priori definition, but as the culmination of a journey rich in discoveries and surprises: a series of experiments designed with the aim of generating both fun and a desire to learn more.

2.1.13 The sea: water that... sustains us!

2

Phase 1:
Qualitative observation of the phenomenon, such as

Water's liquid phase has not a proper form but takes that of the container, while thewater solid state (ice) has a rigid crystalline form.

Liquid waters with different temperatures stratify and do not mix;
an aluminum foil sinks in water while the same foil, if balled, floats;

Phase 2:
Experimentation phase

Learners will perform some buoyancy experiments (with objects of different material but same shape and same volume) or mixing of liquids with different densities.

Phase 3:
Individual observation

Learners will form groups of discussions, and there will be different opinions. Many answers, based on "common sense" will be wrong. In many cases, learned concepts are applied without logic or good reasoning. Some example: the heavy objects will sink, independently of their volume;

During this phase, learners record their considerations in their workbooks. They have to read their conclusions, in order to begin the discussion, during which it is possible to add evidence and correct errors.

Phase 4:
Critical review

Learners will undertake a second series of experiments aimed to disprove perceptions or erroneous interpretations, to break prejudices and to validate positive conjectures. It is important that learners elaborate the solutions by themselves, overcoming the eventual previous errors of interpretation. Learners will reach an effective consolidation of the concept acquired, thanks also to the increased self-esteem. The design of our didactic path is based on this assumption. Example: with the hydrostatic balance, the students perform the double weight experiment and understand that also the metal sample (aluminum, brass) is affected by the Archimedes push: in fact, the weight of the sample inside water is lesser that its weight out of the water! Moreover, in this phase learners are faced with the chemical characterization of water: the representation of the H2O molecule and of its chemical bonds, through construction of models with plasticine and the visualization of the atoms that compose it. Particular attention is given to the fact that it is a polar molecule. The concept of polarity is introduced such as a construction of 3-D models, modeling the bonds through magnets. In this way characterization of fluidity, viscosity and typical properties of liquid have been explained to learners, alternating the use of models with real experiments.

Phase 5:
Formal organization of thought/ transformation of knowledge in competence

Learners can apply the acquired knowledge to other problems and to prove if the acquisition of previous concepts has been effective. They will be able to understand many of the phenomena presented in the last part of the laboratory. This is perhaps the most surprising and amusing part of the path, particularly reached in experiments that often appear as small "magic tricks" or "sleight of hand" to the eyes of learners. It is an important moment: they realize to be able to give a logical explanation to phenomena not previously understood or incorrectly explained. Moreover, learners became aware to coordinate their knowledge and insights to address and solve problems, not necessarily related to schoolwork but also to questions and issues resulting from their personal curiosity. An example: principles that are at the base of marine currents formation are shown by means of mixtures of water with different temperature and salinity, with the possibility to visualize the separation of the layers thanks to the use of food coloring.

2 2.1.13 The sea: water that... sustains us!

During this experience, learners can explain what happens when the red-colored hot water moves upward inside the blue-colored cold water (and the opposite case). Other experiments with cold, hot and salted water bring them to understand the principle at the base of fluid motion in oceans and how the thermoaline circulation arises. Finally, the last 4 work-station are devoted to show how the liquid density influence the floating and buoyancy properties of phytoplanktonic organisms. These are bases to understand their morphological and physiological evolutionary adaptations in order to better exploit the characteristics of the medium in which they live.

A list of necessary materials and included attachment to conduct activity, e.g., Student Instruction Sheet(s), Diagrams, Maps, Tables, Data Sets, etc.

There are 6 work-stations for 6 different themes. Each station must be composed of:
- a table,
- a self-explanatory poster/factsheet about the topic

"Teachers/Students Instruction Sheet" is available in www.parmascienza.it website, in English version, and allow teachers to perform experiments, together with students, following the described and detailed instructions.

Steps the students will need to know to complete activity.

Specific objectives to be reached by students are the following:
Facing science-environmental issues that range from the physical and chemical properties of water to the principles that are the basis of body floating; from how these principles influence life in the ocean to the formation of marine currents and the importance they attach to the climate of the entire earth globe.

Facing issues about the contribution that sea give us in terms of the support of humanity (food, energy production, climate influence etc), how our behavior is changing this delicate balance between sea and land and what are the measures to take to repair before it's too late.

Steps are grouped in 6 "target goals", each one related to the corresponding work-station:

Work-station 1:
What is the sea doing?

Basic concept to be acquired will be:

- The chemical composition of water.
- The peculiarity of the chemical structure of water molecule, producing an "asymmetry of charge", and thus the concept of "polar liquid".
- The importance of "hydrogen chemical bond", that make possible the water to be liquid in "standard" environmental conditions.
- The concept of fluid and liquid.
- Polar and a-polar fluids.

Work-station 2:
The sea-water is....?

Basic concept to be acquired will be:

Body floating and buoyancy Archimede' law
- The concept of "density" and "specific weight", first for solid body and, later, extended to fluids.

Work-station 3:
The sea-water is....?

Basic concept to be acquired will be salinity and its consequences.

- Why is the sea salted.
- The chemical structure of the most common salt: NaCl.
- What are the ions and what means "crystalline structure"?
- Different kinds of salt dissolved in the sea.
- Salinity consequences: density rise and impact on the buoyancy.

2.1.13 The sea: water that... sustains us!

2

Work-station 4: salted water, cold water and hot water?

Basic concept to be acquired will be salinity and its consequences.

Subject deal in this work-station is how salt and temperature influences the density of water. Concepts that students will know during this group of "steps" are:

- How temperature influence liquids (or gas) density: visualization of the concept of density in gases and liquids by means of experiments.
- Ice: the concept of "phase transition", and ice peculiar low density in respect to liquid phase.
- Water stratification in ocean and marine currents.
- The Earth Poles as a Marine Circuit Engine: influence on world climate of even small variation of polar temperatures.

Work-station 5: The seawater

Basic concept to be acquired will be salinity and its consequences.

- Water, and in particular the sea, are also a source of livelihood for humanity (i.e. the importance of the water cycle in the Earth ecosystem).
- Desalination and salt; the latter once it was a precious asset and the salt mills worked for thousands of people along the Italian and European coasts.
- Hydro-generators (tides, currents in marine waters).

Work-station 6: Who lives in the oceans?

Basic concept to be acquired will be marine organisms and their adaptations.

- How light, temperature and pressure influence the adaptations of different animals.
- Plankton and the marine food chain.
- Phytoplankton: the importance of symmetries and alignment of different types of phytoplankton' organisms to float in seawater and compete for light.

Teaching tips and strategies, including discussion questions and answers

Conscious acquisition of concepts and overcoming of epistemological obstacles is facilitated when learners is able to construct mental representations of phenomena. In this process, it is important to avoid - or succeed in correcting – misconceptions, which may arise from acquired knowledge or incorrect interpretations of reality. This result can be achieved with a hands-on approach. As regard to the methodology and teaching strategy two important results seem to arise:

- Stimulus based on surprise, wonder and bewilderment is a powerful activator of interest and leads to the will to overcome the (eventual) initial error of interpretation of a phenomenon. It is what makes them aware of the existence of an obstacle (their misconception) to be removed in order to understand where is "the trick". This step is a fundamental cornerstone in the cognitive process, help to overcome the errors arising from erroneous common-sense explanations and, through this process, lead to the consolidation of the learned concept and ends with the "understanding" of the phenomenon, as reported by recent studies of neurology.

- The former achievement is essential for the correct acquisition and consolidation of knowledge, and for this reason it is important to project didactic paths that allow learners to reach independently the understanding of the concepts and to strength the self-esteem.

Assessment Strategies and learning outcomes defined

It can be proposed a non-standard evaluation methods, such as a set up of theater performance. Learners propose some parts of the laboratory to a generic audience, emphasizing the funny side of the scientific discussion and of the experiments.

2 2.1.13 The sea: water that... sustains us!

Additional suggestions for conducting the activity with younger and/or older audiences and in a non-formal setting

Concepts as specific weight, water salinity, viscosity, molecular polarity are intrinsically difficult. A non-formal didactic approach, developed in a learning environment user-friendly is the opportunity to create a connection between everyday' experience and scholastic knowledge.

This didactic path can be, in fact, adapted also for younger students (last year of primary school), festivals or other no–formal settings.

Additional resources, e.g., websites, printed material, software, data sets, etc.

www.parmascienza.it

References used to develop the activity

Catalogo Parmascienza LAB 2012 "Tocca con mano". Authors: Carlo Mantovani Silvia Merlino, Marco Bianucci, Rosaria Evangelista, Licia Gambarelli and Roberto Fieschi. 2014. EDICTA Ed. Parma. ISBN 978-88-89998-55-7

Il Mare delle CinqueTerre: la costa le correnti, l'ecosistema. Collaborazione ENEA-CNR. Autori: Abate . Barsanti M., Cocitto S. Del Bono I. Ferretti O. Gasparini G., Schirone A. Edizioni "Parco Nazionale delle 5Terre". Patrocinato dal MATT.

Merlino S., Evangelista R., Mantovani C., Bianucci M., Fieschi R. 2015. Oceanography outreach and education in informal and non-formal learning environment. In: Proceedings of Ocean'15 MTS/IEEE conference, Genova 18-21 May 2015.

The activity was originally ideated by CNR Instituteof Marine Science (ISMAR) in collaboration with the cultural scientific association "Parma- Casa della Scienza", and has been published in an Italian language version (see reference quoted in point 3). This version has been adapted from the Italian one (English translation, text and graphics adaptation, content reviewed) and have been enriched with a part that's explicitly dedicated to marine phytoplankton, thanks to Dr. Marinella Abbate of ENEA.

2.1.14 Know, think, act

Know, think, act

90 minutes

Silva, F.; Mata, B.; Geraldes, G.; Costa, R.; Portuguese Ministry of the Sea - DGPM

11-18

6

14 LIFE BELOW WATER

14.1

4 QUALITY EDUCATION

Focus on:

Cognitive learning objectives

I. The learners can be able to identify the main sources of marine pollution.
II. The learners can be able to know the degradation times of different sorts of marine litter.
III. The learners can be able to identify and reflect on the major threats to the marine environment.

Socio-emotional learning objectives

I. The learners can be able to correctly communicate about marine litter in a coherent and informed way.
II. The learners can raise awareness to the dangers of pollution.
III. The learners can realize that "the change" is also in our hands.

Behavioral learning objectives

I. The learners can be able to understand the ocean's influence on man and our influence on the ocean.
II. The learners can be able to realize the importance of protecting the ocean.
III. The learners can be involved in the preservation of the ocean.
IV. The learners can be able to make conscious decisions regarding the ocean.

Focus on, with reference to the UNESCO Education for Sustainable Development (ESD) multi-perspective approach

- **The scientific perspective**
- **The sustainability perspective**

Introduction or background information/ content necessary for teachers to conduct the activity

Marine pollution is one of the main issues of our time. It can be defined as the presence of solid waste and liquid pollutants in the waters of the seas and oceans, as a result of human activity.
This type of pollution comes not only from waste dumped into the sea or spills from vessels, but also from other sources, such as domestic sewage, industrial discharges, and urban and industrial surface runoff.
This activity is about marine litter and what we can do to prevent it. Part of the activity is made in small groups of 4/5 students.

A list of necessary materials and included attachment to conduct activity, e.g., Student Instruction Sheet(s), Diagrams, Maps, Tables, Data Sets, etc.

- Pen or pencil
- Notebooks
- 1 type of marine litter for each group (e.g. plastic cup, water bottle, balloon, cotton swab, aluminum can, fishing net, glass bottle, straws, cigarettes, plastic dishes).
- Worksheet "KNOW, THINK, ACT"

2 2.1.14 Know, think, act

KNOW, THINK, ACT

Type of Marine Litter	
Source of Pollution	
Slogan of the Campaign	
Campaign Goals	
Entities Involved	
Actions	
Target Audience	
Expected Outcomes	

Steps the students will need to know to complete activity

First Step (for the whole class):
- Watch the film "Sources and Impacts of Marine Litter" (https://goo.gl/d9sJii).
- Make a little debate about the film and what we can learn from it.

Second Step (for each group):
- Assign a type of marine litter to each group and distribute the worksheet "KNOW, THINK AND ACT".
- Each group shall fill in the worksheet, planning an original campaign aimed to prevent or inform people about the specific type of marine litter they got.

Third Step (for the class):
- Each group presents its campaign to the class.
- Each group will vote for the best campaign.

Fifth Step (for the class):
- This is the big challenge: To actually implement the best campaign!

Teaching tips and strategies, including discussion questions and answers

- Research the topic on the internet.
- Invite an expert in marine litter for a short talk with the students.
- Read "STOPPING MARINE LITTER TOGETHER!"
- (https://goo.gl/SMujNy).
- Ask the students to bring some type of litter from their homes.
- Start the activity by showing the film "Sources and Impacts of Marine Litter" and start a little discussion about some topics:
  What are the main types of pollution seen in the film?
  What is the influence of marine litter in the food chains?
  Ask the student's opinion on balloons' releases.
  Talk about the degradation times of different sorts of marine litter
- Show some examples of campaigns already implemented (e.g. "Return to Offender", "Stop the Invasion", "Beat the Microbead")

Assessment Strategies, and learning outcomes defined

The evaluation of the acquired knowledge can be done through the presentation of the campaigns developed by the students.

2.1.14 Know, think, act

Additional suggestions for conducting the activity with younger and/or older audiences and in a non-formal setting

It is possible to adapt the language and concepts used in this activity to all levels of education.

Additional resources, e.g., websites, printed material, software, data sets, etc.

http://www.beatthemicrobead.org/
https://ed.ted.com/lessons/how-big-is-the-ocean-scott-gass
https://www.aplixomarinho.org/
https://www.eea.europa.eu/themes/coast_sea/marine-litterwatch
https://goo.gl/duXZQa
http://www.marlisco.eu/
http://www.noaa.gov/resource-collections/ocean-pollution
http://www.noaa.gov/education/education-resource-collections
https://www.surfrider.org/programs/rise-above-plastics
https://www.youtube.com/watch?v=017bBeXhYz4
https://www.youtube.com/watch?v=cwTDvqaqPlM
https://www.youtube.com/watch?v=KpVpJsDjWj8
https://www.youtube.com/watch?v=kQ3jP86QpHA
https://www.youtube.com/watch?v=mGzIz9Ld-sE
https://goo.gl/SMujNy
https://www.sas.org.uk/campaign/return-to-offender/

2

References

[1]
Benefits of Connecting Children with Nature: Why Naturalize Outdoor Learning Environments (January 2012). The Natural Learning Initiative
https://goo.gl/Fr9Aok

[2]
Tilbury, D. and Mulà I. 2009. *Review of Education for Sustainable Development Policies from a Cultural Diversity and Intercultural Dialogue: Gaps and Opportunities for Future Action*. Paris, UNESCO.
http://unesdoc.unesco.org/images/0021/002117/211750e.pdf

[3]
UNESCO. 2015. *Education for Sustainable Development Goals-Learning Objectives,* Paris, UNESCO.
http://unesdoc.unesco.org/images/0024/002474/247444e.pdf

[4]
McKinley E. and S. Fletcher. 2012. Improving marine environmental health through marine citizenship: a call for debate. *Marine Policy* 36(3):839-843.

[5]
College of Exploration. *Ocean Literacy Framework*.
http://oceanliteracy.wp2.coexploration.org/ocean-literacy-framework/

[6]
United Nations. 2017. *Sustainable Development* Goal 14.
https://sustainabledevelopment.un.org/sdg14

[7]
United Nations. 2017. *Sustainable Development Knowledge Platform*.
https://sustainabledevelopment.un.org/sdgs

[8]
UNESCO. 2017. *Education for Sustainable Development Goals-Learning Objectives*, Paris, UNESCO.
(http://unesdoc.unesco.org/images/0024/002474/247444e.pdf)

[9]
UNESCO. 2012. *Exploring Sustainable Development: A Multiple-Perspective Approach*, Paris, UNESCO.
(http://unesdoc.unesco.org/images/0021/002154/215431E.pdf)

Ocean Literacy for All – A toolkit

Ocean literacy is the understanding of our individual and collective impact on the ocean and its impact on our lives and wellbeing.

More than a concept, ocean literacy is a fundamental tool to enhance ocean knowledge, and encourage citizens and stakeholders to have an active role in the implementation of sustainable actions. It is a way to advance sustainable production practices, to develop sound public marine policy, to promote a more responsible citizenry, and to encourage young people to start a career in the blue economy or in ocean science.

This publication takes stock and reviews current ocean literacy approaches, initiatives, programs and projects. Case studies, historical data and cultural information illustrate the essential ocean literacy principles and highlight the underlying scientific knowledge. In addition, interviews with experts, educators, and scientists working and studying all over the world showcase ongoing ocean literacy efforts under a multidisciplinary perspective.

The second part provides fourteen activities, tools and good practices drawing on key competencies required to make learners of all ages aware of and actively committed to addressing sustainable development issues. Educators can adapt the materials provided according to their needs and available resources. Additional references provided alongside each activity allow educators to expand on the proposed themes and materials.

This manual is one of the ways in which UNESCO and its Intergovernmental Oceanographic Commission (IOC) seek to engage countries and stakeholders toward developing culturally diverse, interdisciplinary ocean literacy activities worldwide.

One Planet, One Ocean

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United Nations Educational, Scientific and Cultural Organization

Regional Bureau for Science and Culture in Europe

Intergovernmental Oceanographic Commission

Sustainable Development Goals

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