International Council of Associations for Science Education

ICASE International Bulletin for Science Education

Volume 1

Issue 2

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Left to right; Eoghan Long, Dr Ryan Gallagher,Lynn Ladbrook (ASE chief executive),Marianne Cutler (ASE representative on ICASE), Stephen Murphy, Dr Declan Kennedy at the 2025 ASE conference in the University of Nottingham

Message from the editor

Welcome to the second issue of The International Council of Associations of Science Education International Bulletin!

In this series of bulletins we hope to showcase the best ICASE has to offer in terms of science pedagogy, latest research and updates from around the ICASE community. This bulletin will be issued twice a year initially and we hope you will both enjoy and gain insight into the various events taking place in the world of ICASE!

In our first article, Dr. Sue Dale Tunnicliffe discusses her efforts to ensure that ICASE, originally established to support the work of secondary science teachers, also prioritizes science education in the early years. Her work emphasizes the importance of fostering scientific curiosity and foundational understanding during pre-Kindergarten and early primary school, setting the stage for lifelong learning and engagement with science.

Our second article, we have a gallery of photos showing recent events in the Eureka Centre, University College Cork

Our third article concerns The ICASE Sustainability and Environmental Education Committee Chair, Dr Yasemin Ozdem Yilmaz, attended the International Conference on Education 2024. Dr Ozdem Yilmaz was a panellist in the Forum Discussion concerning the 4th Sustainable Development Goal, Quality Education.

In the fourth article, Dr Carol Aldous informs us about the 55nd annual conference of ASERA held in New Zealand earlier this year and invites us to attend the 56th annual conference to be held in Melbourne Australia in 2025.

In our fifth article, Dr Teresa Kennedy provides an article she wrote for the UN Decade of Ocean Science for Sustainable Development (2021-2030)

We also have a photo gallery from the 2025 ASE annual conference in the University of Nottingham, UK

On the next page, please see the flyer for the ICASE 2026 World Conference, to be held in University College Cork, Ireland

Check out the new ICASE website: https://icaseonline.net/web/

Stephen Murphy
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International Council of Associations for Science Education

ICASE

8TH WORLD CONFERENCE ON SCIENCE AND TECHNOLOGY EDUCATION

22nd - 25th June, 2026 University College Cork, Ireland

- Keynote speakers
- Research papers
- Primary & Secondary Science
- Third level research
- Curriculum developers
- Workshops
- Exhibitions,Tours &Sightseeing

Day for exhibitors: 23rd June, 2026

Enquiries re exhibition space should be made to David O' Brien, Exhibitions Coordinator, at **david.obrien@balcs.ie**

Further information at https://icaseonline.net/web/

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The Paradigm shifts in Science Education since the founding of ICASE 51 years ago.

By Dr Sue Dale Tunnicliffe

Dr Tunnicliffe is a zoologist specializing in education, having started teaching in 1968 Advanced level zoology she pursued her quest to find where learners first interact and start understanding science. She has worked in museums and zoos as well as schools with children from 4 to 19 years.

Now an honorary staff member at University College London's Institute of Education where she was a part time academic , Reader, now Emeritus . She is Chairman of the Commonwealth Association for Science Technology and Maths Educators.

She instigated pre-primary section for ICASE.

*T*he International Council of Associations for Science Education (ICASE) was created in 1972 by the United Nations Educational, Scientific and Cultural Organization (UNESCO) to extend and improve science education throughout the world. Since that time, ASE (the UK Association for Science Education) and NSTA (the U.S. National Science Teaching Association), among many other science teacher organizations around the world, have come together through ICASE to support their science teachers. Three of the ICASE Founders from UNESCO, Sheila Haggis (known as the "Mother of ICASE"), Bob Silberman, and Dennis Chisman, set the stage for a global network of science education organizations, fostering collaboration, resource sharing, and innovative teaching practices to advance science education across cultural and geographic boundaries (see the History section on the ICASE website for more information, https://icaseonline.net/web/icase-history/).

ICASE recognizes that a foundation in science education begins in the early years, as it is essential to nurture curiosity and critical thinking skills from a young age to inspire lifelong learning and a deeper understanding of the world. Play is instinctive and is what young humans do. It is their work (Roth et al., 2013, p. 14). This behaviour is not unique to young humans; it also occurs in other animals and has been identified as both pleasurable and essential for learning key life-saving skills necessary for survival.
In humans, learning through instruction has been documented in indigenous societies, where children often use small-sized replicas of important adult tools to practice and develop skills (e.g., Reide et al., 2018). This parallels the spontaneous reenactment of adult practices often observed in the preschool children I studied (Kennedy & Tunnicliffe, 2022; Tunnicliffe, 2022, 2023; Tunnicliffe & Kennedy, 2022). Fleer (2009) pointed out that playing is 'learning in a roundabout way,' but also emphasized the importance of a mediational scientific framework within formal schooling to enhance learners' experiences. This framework supports the integration of hands-on skills with theoretical understanding to deepen learning.

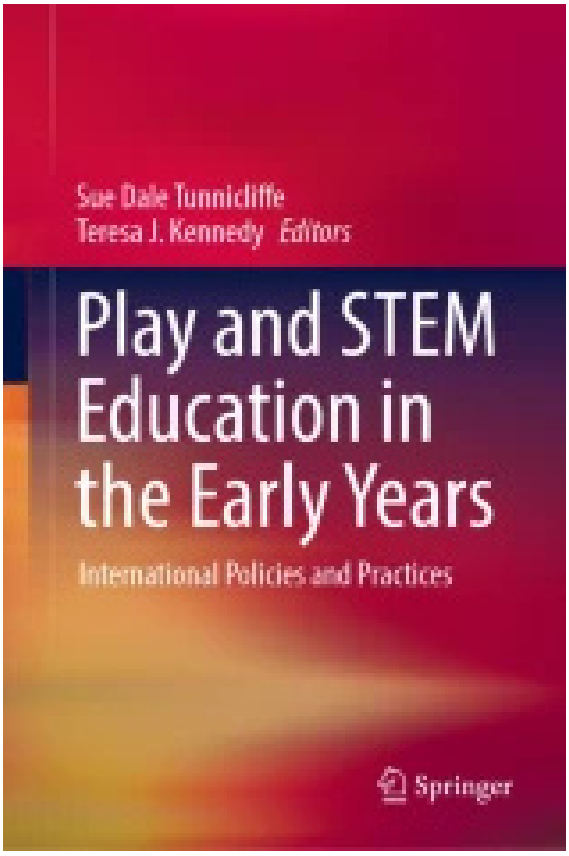
Researchers have also identified that the lack of confidence in STEM understanding among early childhood and primary teachers, which underscores the important role of associations in addressing this issue through practitioner training. However, STEM teachers with 'advanced' knowledge from their degrees and research often find it difficult to analyse the foundational actions and ideas that eventually form the basis of widely accepted concepts, often summarised as scientific laws. Interestingly, non-Stem experts may find it easier to approach and understand these foundational concepts from a fresh perspective. Science and other STEM organizations play a crucial role in identifying these foundational concepts and ensuring that underconfident practitioners can recognize them. Additionally, these organizations can help highlight the overlap between traditionally defined individual subjects to support more integrated teaching approaches.

Sikder and Fleer (2015) identified ‘small science’ episodes, such as water play, occurring in a child’s everyday experiences. Gelman and Brenneman (2004) acknowledged the construction of understanding through free choice interaction with objects such as household items and toys. Toys are in fact 3-Dimesional models (Gilbert, 2008). Children in many societies enjoy climbing and balancing, often exploring these abilities in playgrounds designed with appropriate structures for such activities. Tunnicliffe and Gkouskou (2019) looked at STEM in action on playground equipment. Additionally, Mifford and Tippett (2015, p. 24) identified patterns of learning in early years school children.

However, children thinking and problem solving do not know of the adult inflicted silos of STEM (science, technology, engineering, and mathematics). From birth, children are observing their environment and begin to respond and interact. They progressively learn and acquire skills. They experience and build up understanding of cause and effect from the earliest years. Each small action represents a part of a larger concept—such as forces. These small parts can be thought of as the 'phonics' of STEM education, forming the foundation of understanding. Together, they create a STEM experience (STEM-E), where learning is integrated and meaningful.

Such early, pre-formal instructional experiences in informal learning environments are referred to as Holistic STEM. Through these 'play' interactions, children engage in problem-solving, progressively building their experiences and understanding in small, incremental steps. Moreover, STEM is embedded in everyday life, present all around us in routine activities and interactions in a child’s life as well as in playgroups and nursery environments. Adults interacting with children are often unaware of the STEM concepts unfolding in these moments. Once they recognize them, they have a unique opportunity to support and encourage children by identifying and describing the actions they are engaged in, such as pushing, pulling, or dropping.

Play encompasses many aspects, such as imaginative scenarios and reenactments, but all these actions involve fundamental movements like pushing, pulling, dropping, or throwing. Thus, language literacy is an essential component of developing STEM capital in the youngest learners. Engaging with their spoken languages and using pictorial fiction books (PFB) helps children recognize items and actions, observe STEM concepts in practice, and develop problem-solving skills. Additionally, storytelling is an important part of developing STEM, and it is argued should be given priority along with moving objects in early years (Anastasiou, Kostaras, Kyritsis, & Kostaras, 2015).



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Feature edited by Dr Teresa Kennedy, ICASE Representative to UNESCO

ICASE at UNESCO

The 2024 International Conference of NGOs in Official Partnership with UNESCO was held in UNESCO Headquarters, Paris from 17 - 19 December 2024. The theme of the Conference was "Building Capacity for Action"

The 2024 International Conference of NGOs in Official Partnership with UNESCO (ICNGO 2024) was held at UNESCO Headquarters in Paris from 17-19 December 2024. The theme of the conference was “Building Capacity for Action.” During the event, the UNESCO courtyard proudly displayed its arrangement of international flags representing the organization's commitment to global unity and cooperation, a hallmark of UNESCO's mission. The UNESCO headquarters in Paris is a hub for fostering dialogue and collaboration among its member states, and its courtyard serves as a symbolic and physical space for international engagement, aligning with UNESCO's role in fostering international cooperation in education, science, and culture.

Teresa, concluding her term as Vice-President of the NGO UNESCO Liaison Committee representing ICASE, had the honor of collaborating with the committee to organize and execute this significant event. The International Conference of NGOs in Official Partnership with UNESCO (ICNGO) is mandated by UNESCO’s Directives concerning partnerships with Non-Governmental Organizations (NGOs) and convenes every two years in December. This conference serves as a vital platform for NGOs to engage with UNESCO’s priority actions, deliberate on collective priorities for the future, and elect a new NGO-UNESCO Liaison Committee.

Dr Teresa Kennedy speaking at the UNESCO conference.

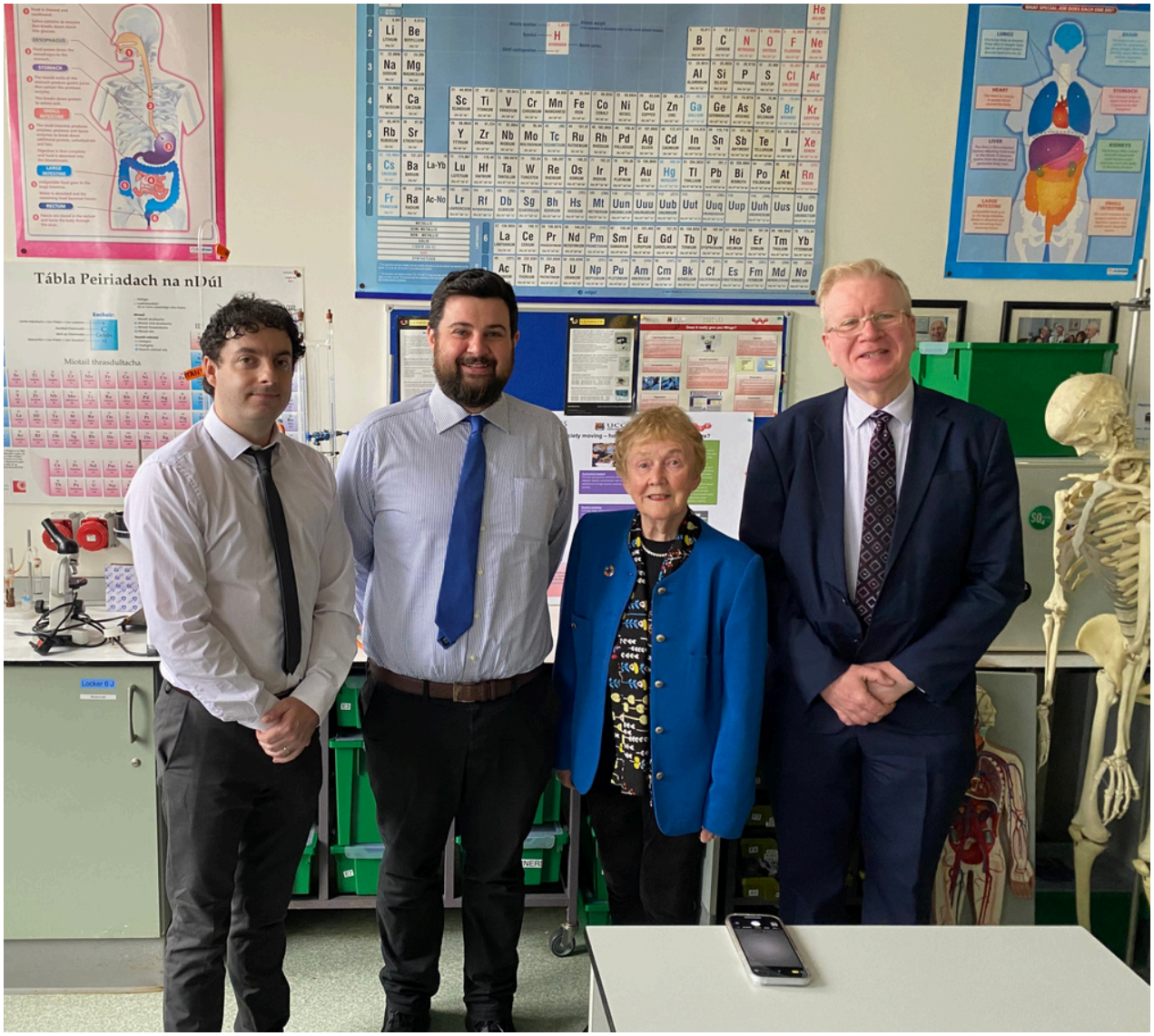
ICASE holds the title of an “NGO in Official Partnership with UNESCO, with consultative status.” Additionally, Teresa in her role as Co-Chair of the UNESCO IOC Ocean Decade Task Group, presented the new IOC Ocean Decade Manual for NGOs, which is a comprehensive resource designed to inspire and guide participation in and contributions to the Ocean Decade

From left to right: Dr Teresa Kennedy and Dr. Declan Kennedy represented ICASE at the ICNGO 2024.

Recent events at The Eureka Centre, UCC

There have been a busy few months in the Eureka Centre in University College Cork!

Our first visitor was Prof. Áine Hyland, who is Emeritus Professor of Education and former vice-president of University College Cork, Ireland.



Dr Ryan Gallagher, Stephen Murphy, Prof Áine Hyland and Dr Declan Kennedy in the Eureka Centre, University College Cork

Our second visitor was Dr Steven Sexton, lecturer of Science Education at the University of Otago, New Zealand. Dr Sexton stayed in Cork, Ireland for one month as a visiting academic. It was a pleasure to have Dr Sexton in the Eureka Centre for the visit and our student science teachers learned a lot from him.

In the below photo, we see Dr Declan Kennedy making a presentation to Dr Steve Sexton as a token of appreciation for his visit to the Eureka Centre.

Left to right; Prof Nicola Ingram (Head of Education, UCC), Dr, Steven Sexton, Dr Declan Kennedy, Stephen Murphy, and Dr Ryan Gallagher in University College Cork

Malmö University Delegation Visit to the School of Education, UCC

The visit by the Mälmö University delegation to UCC's School of Education fostered a spirit of collaboration and mutual learning.
The discussions highlighted shared priorities in education, research, and international engagement, paving the way for potential partnerships.

Stephen Murphy, Dr, Ryan Gallagher, Dr Torun Mattsson (Malmö University) , Dr Mats Lundström (Malmö University) , and Dr Caroline Morand (Malmö University) in the Eureka Centre, University College Cork

Jessica Cole, who recently graduated top of her class in her BSc (Ed), was awarded the Declan Kennedy medal for her achievements. She was honoured with a ceremony in the Eureka Centre in UCC. Well done Jessica!

Jessica Cole (centre) with UCC School of Education staff and family members in the Eureka Centre, UCC

In Memory of Dr. Virgilio U. Manzano (1954–2024): Honoring a Legacy of Excellence in Science Education in Asia

In Memory of Dr. Virgilio U. Manzano (1954–2024): Honoring a Legacy of Excellence in Science Education in Asia

It is with great sorrow that we mourn the passing of Dr Virgilio U. Manzano, an exceptional scholar and cherished member of the science and technology education community. His departure leaves an irreplaceable void in the hearts of his colleagues, students, and all who had the privilege of knowing him.

Dr. Virgilio U. Manzano began his academic journey at Pangasinan State University, earning bachelor ′s degrees in Elementary Education and Secondary Education, with a major in Physics. His professional career commenced as an elementary and high school science teacher, after which he served as a faculty member at his alma mater for ten years. In 1980, he received a prestigious Japanese Government (MEXT) scholarship to pursue a Diploma in Teacher Education at Hiroshima University. He subsequently completed a PhD in Education, specialising in Curriculum Studies, at Hiroshima University from 1984 to 1987. His dissertation, Factors in Science Education Correlates of Adolescent Students' Logical Thinking Skills in the Philippines and Japan, was an extensive and pioneering work spanning over 1,000 pages. Dr Manzano joined Hiroshima University as an Assistant Professor in 1988 and was promoted to Associate Professor in 1994. During his tenure there, he collaborated with Dr Shigekazu Takemura on grant-funded scientific projects in science education. He authored numerous journal articles that significantly advanced the field of science education.

In the early 2000s, Dr Manzano returned to the Philippines and joined the College of Education at Diliman University of the Philippines. He held various leadership roles, including Chair of the Division of Curriculum and Instruction (2016–2019), Cluster Coordinator of the EDFD-EDCS-NFE Cluster (2015-2016), College Secretary (2008–2009), and Director of the UP Center for International Studies (2006–2007). He also maintained close ties with Japan, serving as a Student Adviser for the Japan Information and Cultural Center at the Japanese Embassy in Manila and as a Training Adviser for the Japan Foundation Manila Office. After retiring from the University of the Philippines, he continued his academic contributions as Dean of the Institute of Graduate and Advanced Studies at Urdaneta City University from 2021 to 2024.

Dr. Manzano was a staunch advocate of educational internationalisation, forging collaborations among Asian universities that enabled Filipino graduate students to pursue

studies abroad. He dedicated himself to organising conferences, training sessions, and seminars to enhance the pedagogical skills and performance of public and private school teachers. His passion for science education, community-based learning, and curriculum development was unwavering. He firmly believed that education should be accessible to all and that a nation ′s progress is intrinsically linked to the quality of education provided to its citizens.

Dr. Manzano ′s legacy endures through his ground-breaking contributions, the students he inspired, and the countless lives he touched. May his memory serve as a source of inspiration to all who strive for excellence in education.

Manabu Sumida, Professor, Ehime University
Takuya Matsuura, Professor, Hiroshima University
Greg T. Pawilen, Professor, University of the Philippines Los Banos
Ferdinand Martin, Assistant Professor, University of the Philippines Diliman
Joel B. Faustino, Associate Professor, Bulacan State University

Further details can be found here: https://educ.upd.edu.ph/dr-virgilio-u-manzano-november-7-1954-june-16-2024/

The University of Nottingham hosted the annual ASE conference from 9th to 11th January 2025

The main themes of the conference were:

- Artificial Intelligence and Science Education
- Curriculum, Assessment and New Teaching Approaches
- Inclusion and Diversity
- Practical Work
- Professional Journeys
- Research
- Sustainability
- Climate Change
- Environmental Issues
- Wellbeing
- Effective Working Practices

The three days included over 250 sessions with keynotes, speakers and workshops offering a broad scope of professional development, along with a fantastic exhibition of publishers, exam boards, organisations and resource suppliers, as well as social events and more.

Mr Eoghan Long (ICASE Representative), Sir Martyn Poliakoff (University of Nottingham), Mr Simon Poliakoff (The Priory School Hitchin), Mr Stephen Murphy (School of Education, UCC), Dr Declan Kennedy (School of Education, UCC) and Dr Ryan Gallagher (School of Education, UCC) at the 2025 ASE conference in the University of Nottingham

INCOED 2024 Conference

Dr. Yasemin Ozdem Yilmaz is a science education researcher at the Department of Primary Education at Mugla Sitki Kocman Universitesi (MSKU), Turkiye. Dr. Ozdem Yilmaz is a member of the International Council of Associations for Science Education (ICASE), Science Education and Research Association in Turkey (FEAD), and Science Teachers Association in Turkey (FENODER).

The ICASE Sustainability and Environmental Education Committee Chair, Dr Yasemin Ozdem Yilmaz, attended the International Conference on Education 2024 centring on the theme entitled ''Inclusive and Innovative Education for Sustainable Futures: Unlocking Opportunities for All''.

The Faculty of Education and Humanities of UNITAR International University, Malaysia, organised the International Conference on Education 4.0 2024 (INCOED 4.0 2024). The conference aims to promote the advancement of theory, research, and practices in education. It provides a platform for researchers, practitioners, and educators to present and discuss the latest innovations, trends, concerns, and practical educational challenges. Additionally, by bringing together educators from various backgrounds, this conference seeks to bridge the knowledge gaps and address the learning loss resulting from educational inequity and crises. It also promotes the idea of education without borders.

Dr Ozdem Yilmaz was a panellist in the Forum Discussion concerning the 4th Sustainable Development Goal, Quality Education, along with Datin Lucille Lopez (Teacher, Malaysia) and Dr Shamsul Nizam bin Kachi Mohideen (Principal Assistant Director of the Ministry of Education Malaysia). Dr Ozdem Yilmaz contributed to the discussion with evidence and views about the inclusivity in education beginning from the early childhood years and teachers' education regarding the inclusivity of children and community.

ICASE was well represented at this event, with Dr. Teresa Kennedy serving as the Keynote Speaker, and Dr. Manabu Sumida serving as a Featured Speaker. For more information, see https://www.unitar.my/incoed2024/.

Keynote Speaker

UTTyler

Prof. Dr. Teresa J. Kennedy

Professor of International STEM and Bilingual/ELL Education
University of Texas
United States of America

Featured Speaker

愛媛大学
EHIME UNIVERSITY

Prof. Dr. Manabu Sumida

Professor of Science Education
Faculty of Education
Ehime University
Japan

Forum Panelist

MUĞLA SITKI KOÇMAN ÜNİVERSİTESİ

Assoc. Prof. Dr. Yasemin Ozdem Yilmaz

Science Education Researcher
Department of Primary Education
Mugla Sitki Kocman Universitesi (MSKU)
Turkiye

News from Australasia

Dr. Carol Aldous
Australia/Pacific Regional Representative
carol.aldous@flinders.edu.au

Australasian Science Education Research Association (ASERA)
recent and future (annual) meetings.

The Australasian Science Education Research Association (ASERA) successfully held its 55th Annual Conference in Albany New Zealand from 2nd to 5th July at Massey University, Auckland Campus. The conference was conducted face to face with participants attending from Australia, China, Finland, Germany, Hong Kong, India, Japan, Namibia, New Zealand, Singapore, South Korea, Taiwan, Thailand and the USA.

The next annual conference, ASERA 56, is planned for Melbourne, Australia at Deakin University, 'Deakin Downtown, Melbourne Docklands' from Tuesday 1st July to Friday 4th July 2025. Submissions from international participants are most welcome. Please see flyer to follow.

Image: Impress Air / Visit Victoria

Tuesday 1st–Friday 4th July 2025

Deakin Downtown, Melbourne Docklands, Australia

As one of the oldest and most highly regarded Science Education research associations in the world, we are delighted to unite Science Education researchers and educators from Australia, New Zealand, the Asia-Pacific region, and beyond through our annual conference to exchange ideas that transform the field of Science Education.

We invite you to join us for our 56th annual conference (ASERA56) at Deakin Downtown, Melbourne Docklands from July 1 to July 4.

Key Dates:

- Call for abstracts open: November 2024
- Abstract deadline: February 2025
- Early bird & presenter registrations open: March 2025
- Early bird & presenter registrations close: April 2025
- Standard registrations close: June 2025

Key Events:

- 1 July 2025: Welcome Reception
- 2 July 2025: Parallel Presentations Day 1, & HDR/ECR Fireside Chat
- 3 July 2025: Parallel Presentations Day 2, ASERA AGM, Gala Dinner
- 4 July 2025: Parallel Presentations Day 3

Supported by:

DEAKIN UNIVERSITY

Please see the **ASERA56 Website** for more information.

AUSTRALIAN SCIENCE TEACHERS ASSOCIATION

STAWA SCIENCE TEACHERS' ASSOCIATION OF WESTERN AUSTRALIA

ConASTA 72

Eyes to the Future

July 7 -10 2025

Mon 7 July to Thurs 10 July 2025
Pan Pacific Hotel
Perth – Western Australia

Hosted by the Australian Science Teachers Association (ASTA), this conference features:

– Streams on
- Quantum Sciences
- Climate Science and Energy Sustainability
- Physics and Space Sciences
- Chemistry and Forensic Science
- Psychology and Medical Sciences
- Biological and Environmental Sciences
- Earth and Agricultural Sciences

– Keynotes and workshops by leading educators and researchers

– Networking with Australian and International science educators

– Member registration rates for international delegates

www.stawa.net/conferences/conasta

International Symposium on Teaching Einsteinian Physics

Dates: Friday 11 July & Saturday 12 July 2025
Location: The University of Western Australia, Perth
Theme: Integrating contemporary physics concepts into classrooms

Highlights:

- Interactive discussions
- Networking opportunities
- Innovative teaching strategies
- Physics education research

Register: www.einsteinianphysics.com/international-symposium-for-teaching-einsteinian-physics

Skydive Geronimo
Tourism Australia

WA Museum Boola Bardip, Perth
Tourism Western Australia

Ozone at Optus Stadium, Burswood
Tourism Western Australia

Chapter

Advancing Ocean Sustainability for Climate-Resilient Change

Teresa J. Kennedy

By Dr Teresa J. Kennedy
ICASE Representative to UNESCO & NGO UNESCO Liaison Committee Vice President and IOC Ocean Decade focal point.

Abstract

The United Nations (UN) Decade of Ocean Science for Sustainable Development spans from 2021 to 2030 as a global call to action for marine scientists and Early Career Ocean Professionals (ECOPs) to collaboratively create, implement, and communicate science-based solutions to the critical challenges faced by our shared Ocean. The Decade integrates science, policy, and international engagement of a broad base of civil society stakeholders through interdisciplinary research challenges aimed at establishing sustainable marine practices to confront issues related to climate change. This chapter presents a synopsis of the UN-led initiatives that culminated in the launch of the Ocean Decade and describes the global vision articulated in the UN 2030 Agenda for Sustainable Development, focusing on Sustainable Development Goal 14, *Life Below Water*. The critical need for multidisciplinary Ocean research and innovation, collaborative sharing of findings grounded in data, and recommendations for global mitigation and policy development are discussed. The Global Ocean Ship-based Hydrographic Investigations Program (GO-SHIP) is recognized as an exemplary Ocean Decade endorsed action, offering collaborative research experiences and opportunities to contribute to data-driven recommendations influencing policy development on an international scale. Enhancing Ocean literacy through the dissemination of precise, data-driven information is essential for advancing Ocean sustainability for climate-resilient change and safe-guarding the well-being of our Ocean.

Keywords: climate change research, Early Career Ocean Professional (ECOP), GO-SHIP Evolve, Ocean Decade, Ocean literacy, sustainable development goals (SDGs), sustainable marine practices

1. Introduction

International cooperation is paramount in addressing global challenges such as climate change and its impact on our Ocean. As a response to this need, the United Nations (UN), established in 1945 in the aftermath of World War II, plays a crucial role as a global organization uniting 193 countries to collaboratively address challenges affecting our well-being and the health of our planet [1]. Policies are agreed upon during the annual UN General Assembly (UNGA), which convenes each year in September at the United Nations Secretariat Building in New York City to engage in

concurrent sessions until all global issues on their agenda have been addressed. Given the critical nature of the topics discussed, sessions typically extend for a 12-month period and conclude shortly before the commencement of the subsequent General Assembly the following year. Diplomatic dialog during high-level meetings and summits at each UNGA result in resolutions (formal statements that carry significant political and moral influence, prompting international norms and practices) and declarations (reports outlining the collective views of all 193 member states). Additionally, the UNGA organizes specific "conventions" to negotiate transparent and inclusive frameworks for international agreements and treaties that promote cooperative multilateral diplomacy, global problem-solving, international legal frameworks, standardization of practices, and mechanisms for monitoring and enforcing compliance of internationally agreed upon initiatives.

Thirteen years following the establishment of the United Nations, concerns related to the world's Ocean gained prominence and became a priority. The first formal UN Conventions on the Law of the Sea (UNCLOS) occurred in 1958 in Geneva, Switzerland, and focused on four separate themes which established formal maritime regulations defining the rights and responsibilities of the UN member states. **Table 1** provides specific actions established at each of the four initial conventions [2].

The Geneva UNCLOS essentially outlined the first global framework for Ocean usage. However, while it touched on certain environmental safeguards, such as sanitation, it granted member states the power to decide how to implement strategies and enforce policies. Consequently, the consistency and effectiveness of the planned environmental protections differed from one country to another.

Twenty-four years later, in 1982, the UN member states agreed upon a more concerted global effort aimed at addressing the implementation of the Geneva UNCLOS. This international treaty provided the legal framework for use, and importantly, the protection of the world's Ocean. It is a widely accepted global agenda for Ocean governance and is often referred to as one of the most comprehensive and significant instruments of international law. Nonetheless, it took an additional 12 years to secure approval in 1994 from all member states to uniformly adopt the updated UNCLOS. Still, no formal reporting on the global state of the Ocean had occurred to that point, and furthermore, none was planned for in the foreseeable future.

Convention theme	**Focus and outcome** Established the concept of the territorial seas
Convention 1: Territorial Sea and the Contiguous Zone (CTS)	(the belt of coastal waters extending 12 nautical miles from a coastal state), and the contiguous zone (waters extending an additional 12 miles beyond the territorial sea); gave states jurisdiction to enforce laws related to customs, fiscal matters, immigration, and sanitary regulations.
Convention 2: The High Seas (CHS)	Outlined the freedoms of the high seas for all states; established principles of navigation, fishing, and scientific research.
Convention 3: Fishing and Conservation of the Living Resources of the High Seas (CFCLR)	Established international rules for the conservation and management of marine living resources in the high seas.
Convention 4: Continental Shelf (CCS)	Established principles for the delimitation of the continental shelf between adjacent or opposite states.

Table 1.
Geneva 1959 UN conventions on the law of the sea (UNCLOS).

Another nine years passed before the UNGA successfully established an agreed upon process for regular reporting and assessment of marine environments on a global scale through UNGA Resolution 57/141, *Oceans and the Law of the Sea* in 2003. The UNCLOS spent the next two years formalizing plans to conduct an *Assessment of Assessments* (AOA) and assembled an international Group of Experts in 2005 to oversee the four-year process. The final report on the AOA was released in 2009, inspiring UNGA Resolution 64/72 to request a global assessment of the state of the world's Ocean, specifically focusing on the relationships between the Ocean and humans, covering ecological, economic, and social dimensions [3].

In 2010, the First World Ocean Assessment (FWOA) was released. It successfully drew global attention to the concerning condition of the Ocean and emphasized the urgent need for improved management of coastal and marine environments to safeguard crucial ecosystem services [4]. Results of the FWOA report were shared globally at the UNGA in September 2015, adding the Ocean to a longer list of areas of concern regarding the maintenance of a globally sustainable planet. The adoption of UNGA Resolution 70/1, *Transforming our World: The 2030 Agenda for Sustainable Development*, was the first collaborative global initiative to create a foundational plan aimed at cultivating health, peace, and prosperity for both humanity and the planet, spanning the present and future [5]. **Table 2** provides an overview of the historic initiatives undertaken by the UN, beginning in 1958 with the Geneva UNCLOS and culminating in the formulation of the *2030 Agenda for Sustainable Development* in 2015. This table documents the chronological progression leading to global awareness of Ocean health, highlighting the pivotal year of 2003 when the groundwork for consistent monitoring of worldwide marine environments was established and the creation of Agenda 2030 and the Sustainable Development Goals (SDGs) in 2015.

Finally, 57 years after the Geneva UNCLOS, the UN successfully drew attention to the critically urgent need of governments around the world to work together to protect our shared Ocean. Many member states began calling for urgent action to safeguard the health of our Ocean, and widespread dissemination of reports documented an alarming picture [6].

The 2030 Agenda stresses the need for increased Ocean research and data collection, better dissemination and communication of findings, and improved implementation of marine management policies and strategies worldwide. A fundamental aim of the 2030 Agenda is to halt global environmental degradation, which naturally encompasses efforts to address concerns related to the well-being of our Ocean.

Secretary-General Antonio Guterres of Portugal, the Chief Administrative Officer of the UN, explained that although the Ocean connects us all, we have taken it for granted to the point that today, "we face an 'Ocean Emergency' and the tide must be turned … our failure to care for the Ocean will have ripple effects across the entire 2030 Agenda" ([7], paras. 6–7).

2.Addressing the Ocean Emergency

Through the UNGA adoption of the 2030 Agenda, member states acknowledged the health of the world's Ocean as one of the most pressing developmental challenges we face today. They further emphasized its significance, along with the legal frameworks governing global activities related to promoting sustainable and equitable use of the Ocean and its resources through Resolution 72/73, *Oceans and the Law of the Sea* [8]. The 2030 Agenda and Resolution 72/73 would not have occurred without the

Year	United Nations and General Assembly Actions	Time span for actions to occur	Total ye a rs
194	Establishment of the United Nations		
5 195 8	Geneva UN Conventions on the Law of the Sea (UNCLOS), first Global Framework for Ocean usage	13 years after UN es tabl i sh ed	
1982	United Nations Convention on the Law of the Sea (UNCLOS) Treaty proposed protection of the Ocean	24 years after the Geneva U NC LOS	24
1994	Adoption of the UNCLOS Treaty	12 years for agreed upon adoption	36
2003 (23 December)	UNGA Resolution 57/141, *Oceans and the Law of the Sea,* established regular process for global reporting and assessment of the world's marine environment	9 years to establish need for on-going reporting process	45
2005	UNGA document A/60/91 formalized plans to conduct an Assessment of Assessments (AOA); convened Group of Experts	2 years to plan the Assessment of Assessment	47
2009 (1 September) (4 December)	AOA Report presented by the Group of Experts UNGA Resolution 64/72, *Sustainable fisheries...,* approves First Global Integrated Marine Assessment	4 years to complete AOA and approve FWOA	51
2010	First Global Integrated Marine Assessment (First World Ocean Assessment, FWOA)	1 year to create FWOA	52
2015 (September 1) (September 25) (December 23)	FWOA assessment and summary released; UNGA Resolution 70/1, *Transforming our World: The 2030 Agenda for Sustainable Development;* Sustainable Development Goals (SDGs) defined UN Resolution 70/235, *Oceans and the Law of the Sea,* approved the FWOA assessment and summary	5 years to conduct assessment, release global report, and establish Agenda 2030 and the SDGs	57

Table 2.
United Nations General Assembly (UNGA) actions leading to the 2030 agenda.

collaborative agreement of governments around the world to share information about the state of marine environments globally. "The politically controlled process and scientifically compiled FWOA were successful in establishing a politically accepted set of credible Ocean facts" ([9], p. 11). In December 2015, UN Resolution 70/235, *Oceans and the law of the sea,* approved the FWOA assessment and related conclusions.

It is important to note that international input into the resolution referred to different regions of this vast body of water as separate Oceans (e.g., the Atlantic Ocean, the Pacific Ocean, the Indian Ocean, etc.), however the concept of one interconnected global Ocean gained prominence immediately following Resolution 72/73, reflecting the growing awareness of the unity and interdependence of Earth's oceanic systems, encompassing everything from currents and marine life to geological features and climate interactions. The emphasis on the singular "Ocean" highlights the holistic approach needed to successfully address global environmental issues, bringing member states together to work collaboratively to address the current Ocean emergency.

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2.1 UN Sustainable Development Goals

In support of the 2030 Agenda for Sustainable Development, a global set of Sustainable Development Goals (SDGs), along with accompanying targets and indicators, were established to mobilize international efforts between governments, businesses, civil society, and individuals ([5], p. 13). The SDGs are a cohesive set of interdependent objectives aligned with the 2030 Agenda covering "global challenges that are crucial for the survival of humanity" ([10], p. 6). The SDGs address a range of global challenges, including social, economic, and environmental issues [11]. Each of the 17 goals (see **Figure 1**) addresses different aspects of sustainable development and encourages governments around the world to set national targets and incorporate their goals into national planning processes, policies, and strategies. The interconnectedness of the goals recognizes that achieving one goal often involves addressing multiple aspects of sustainable development, therefore uniting efforts between the goals [11, 12].

Figure 1.
UN sustainable development goals. Image source: https://sdgs.un.org/goals.

2.2 Life Below Water

Numerous factors contribute to the poor state of our marine environment. SDG 14 challenges the international community to acknowledge the transboundary nature of marine resources and threats to Ocean sustainability, and to collectively work toward solutions to shared problems through innovative research and governance ([13], p. 5). *Life Below Water* calls on all countries and stakeholders to conserve and sustainably use the Ocean and marine resources through ten targets [14]. These include:

14.1 Prevent and reduce marine pollution.
14.2 Protect and restore marine and coastal ecosystems.
14.3 Minimize and address the impacts of Ocean acidification.

14.4 Promote sustainable fishing.
14.5 Conserve coastal and marine areas.
14.6 End subsidies contributing to overfishing and unregulated fishing.
14.7 Increase the economic benefits from sustainable use of marine resources.
14.8 Increase scientific knowledge, research capacity, and technology for Ocean health.
14.9 Support small scale fishers.
14.10 Enhance the conservation and sustainable use of the Ocean and its resources as reflected in the UN Convention on Law of the Sea.

While SDG 14 focuses on *"Life Below Water"* and aims to conserve and sustainably use marine resources for sustainable development, it is directly interconnected

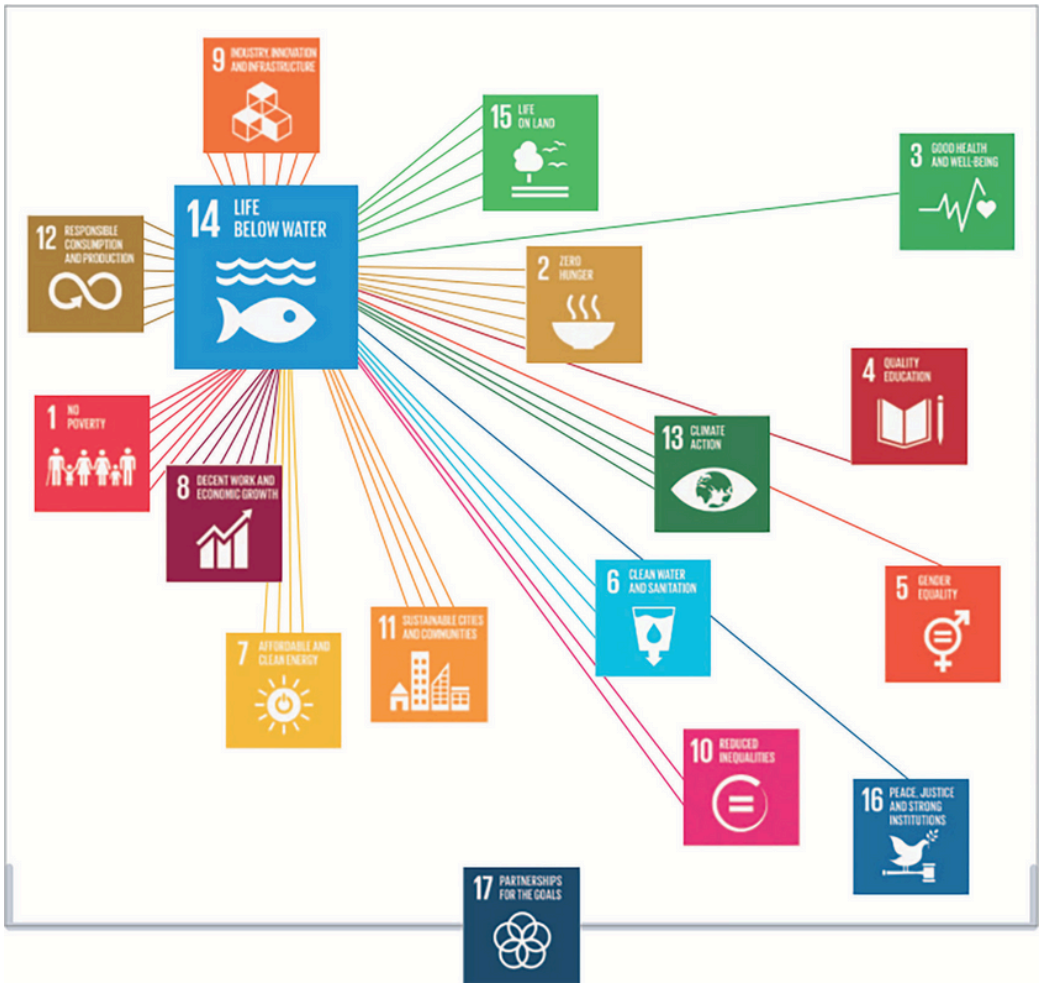

Figure 2.
The central role of Ocean health to global sustainable development. Image source: Institute for Advanced Sustainability Studies ([13], p. 9).

with the other SDGs since actions taken to achieve this goal generally result in either positive or negative impacts on the others. For example, a healthy Ocean and healthy marine ecosystems contribute to the livelihoods of millions of people, especially those in poverty who rely on fisheries and coastal resources for sustenance and resources (e.g., SDG 1: No poverty). **Figure 2** ([13], p. 9) and **Figure 3** [15] highlight connections between SDG 14 and the other SDGs, emphasizing the central role of Ocean health to attaining sustainable development globally. While **Figure 3** specifically focuses on the key interactions between three of the SDGs (SDG 2: Zero Hunger; SDG 3: Good Health and Wellbeing; SDG 7: Affordable and Clean Energy) to provide an example entry point, **Table 3** provides example connections between each of the SDGs and SDG 14, *Life Below Water* [16–20].

A literature review conducted by Barakat et al. [21] revealed strong interlinkages between the SDGs (pp. 23–24), suggesting the importance of wide dissemination of scientific research findings to reinforce the five "Ps of Sustainable Development"—people, planet, prosperity, peace, and partnership (p. 7). The health of the Ocean is crucial for advancing global efforts toward sustainable development, and therefore actions must

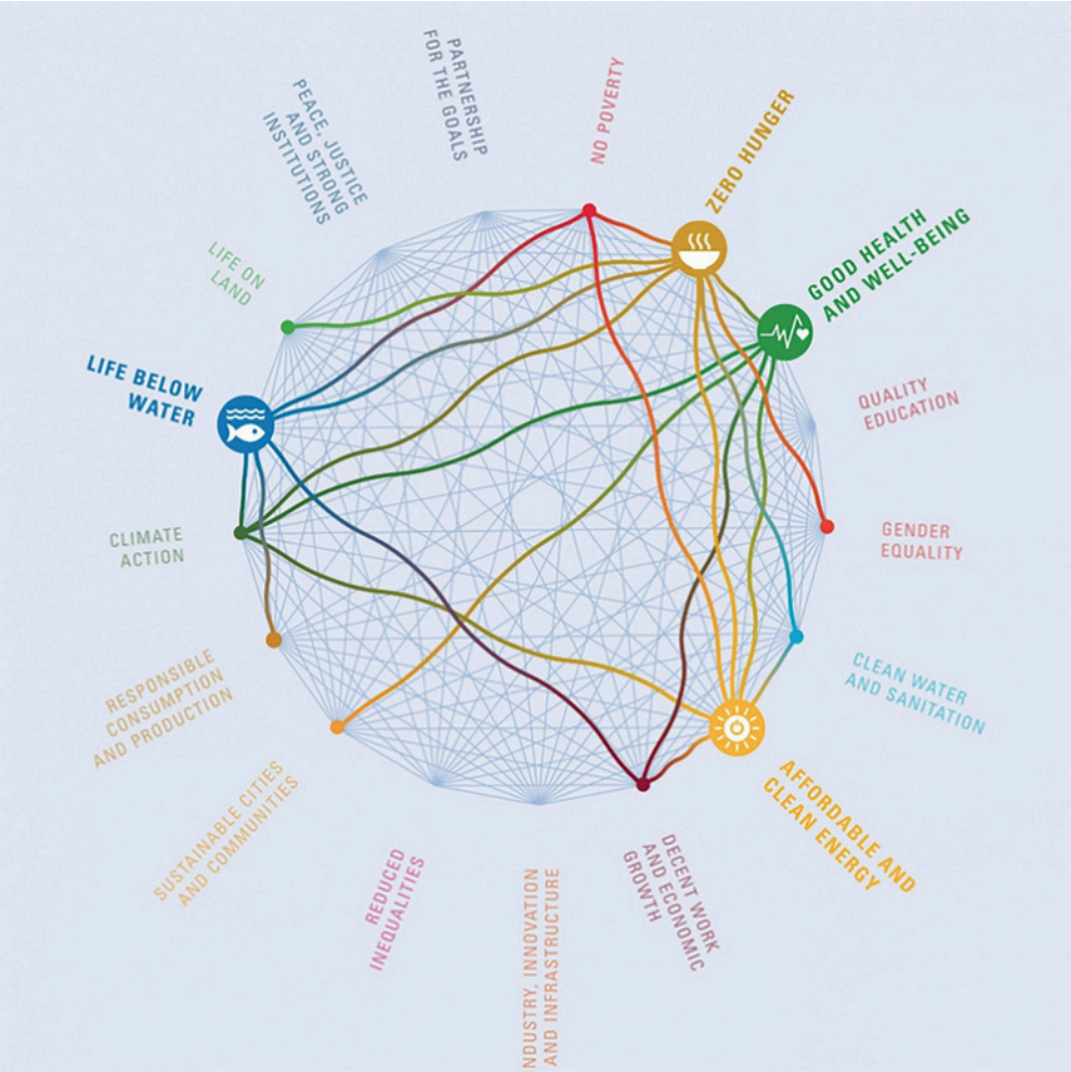

Figure 3.
SDG interactions analyzed using a seven-point rating scale and based on reviews of scientific findings and expert knowledge. Image source: (ICSU, 2017; [15]).

Sustainable development goal	**Example connection to SDGs 14**
1 End poverty in all its forms everywhere	Livelihood of more than three billion people depend on coastal and marine ecosystems.
2 End hunger, achieve food security and improved nutrition and promote sustainable agriculture	"Blue foods" are the primary source of protein for around three billion people; sustainable marine resource management ensures food security.
3 Ensure healthy lives and promote well-being for all at all ages	Microorganisms in the Ocean produce half of the oxygen we breathe; the Ocean regulates freshwater cycles providing drinking water; blue foods provide protein to billions; mental well-being.
4 Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	Ocean literacy fosters life-long emotion connections to the environment and prepares the "blue workforce."
5 Achieve gender equality and empower all women and girls	Gender equity in the blue workforce boosts global GDP and contributes to the blue economy.
6 Ensure availability and sustainable management of water and sanitation for all	Sea-level rise results in saltwater intrusion into freshwater aquifers and water sources; warming Ocean water disrupts freshwater cycles; Ocean plastic flows from around 1600 rivers globally.
7 Ensure access to affordable, reliable, sustainable, and modern energy for all	Growing markets for offshore wind, tidal stream, and wave energy.
8 Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all	Aquaculture and fishing, energy, shipping, tourism; and jobs in conservation, marine research and science, communications, engineering, maritime law.
9 Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	90% of globally traded goods travel by sea; shipping contributes to global greenhouse gas emissions; "green" infrastructures protect people, homes, buildings, power networks from storm damage and sea level rise.
10 Reduce inequality within and among countries	Small island developing states are the most vulnerable to sea-level rise, extreme weather, marine heatwaves, and Ocean acidification.
11 Make cities and human settlements inclusive, safe, resilient, and sustainable	Coastal communities are vulnerable to sea-level rise and extreme weather; serving as hubs for innovative climate solutions such as blue-green infrastructures (protecting/ creating wetlands, oyster beds, barrier islands, etc.).
12 Ensure sustainable consumption and production patterns	Sustainable use and management are essential to reduce undesirable disturbances to marine ecosystems such as litter, plastic waste, chemical contamination, high demand for blue foods.
13 Take urgent action to combat climate change and its impacts	Ocean regulates Earth's climate; warming waters and melting glaciers result in sea-level rise and Ocean acidification; blue carbon projects fight climate change and biodiversity loss.
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	Ocean provides 75% of the rainwater and 50% of the oxygen needed for life on land; helps to protect terrestrial ecosystems from excess heat.

Sustainable development goal	Example connection to SDGs 14
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	UN-led high-level meetings, summits, and conventions; resolutions and declarations such as the UNCLOS resulting in global actions, such as the March 2022 resolution to end plastic consumption and governance of marine resources.
17 Strengthen the means of implementation and revitalize the global partnership for sustainable development	Funding partnerships support a sustainable Ocean economy and global Ocean health (e.g. partnerships with Indigenous communities).

Table 3.
Connections between SDG 14, Life Below Water*and other SDGs.*

be approached through a holistic lens that implements ongoing impact assessments to monitor and adapt strategies in an informed manner. It is critically important that scientific research efforts consider the broader context and potential "ripple effects" that may result from well-intended efforts to avoid unintended consequences.

In 2019, the preliminary draft of the *Technical Guidance on Ocean Accounting for Sustainable Development* was created in response to country demands for a set of guidelines and methodologies to integrate the value of the Ocean into their national accounting systems [22].

This international effort aimed to develop sustainable development practices and inform policy decisions worldwide. After undergoing international review and revision, the official document was circulated throughout the UN.

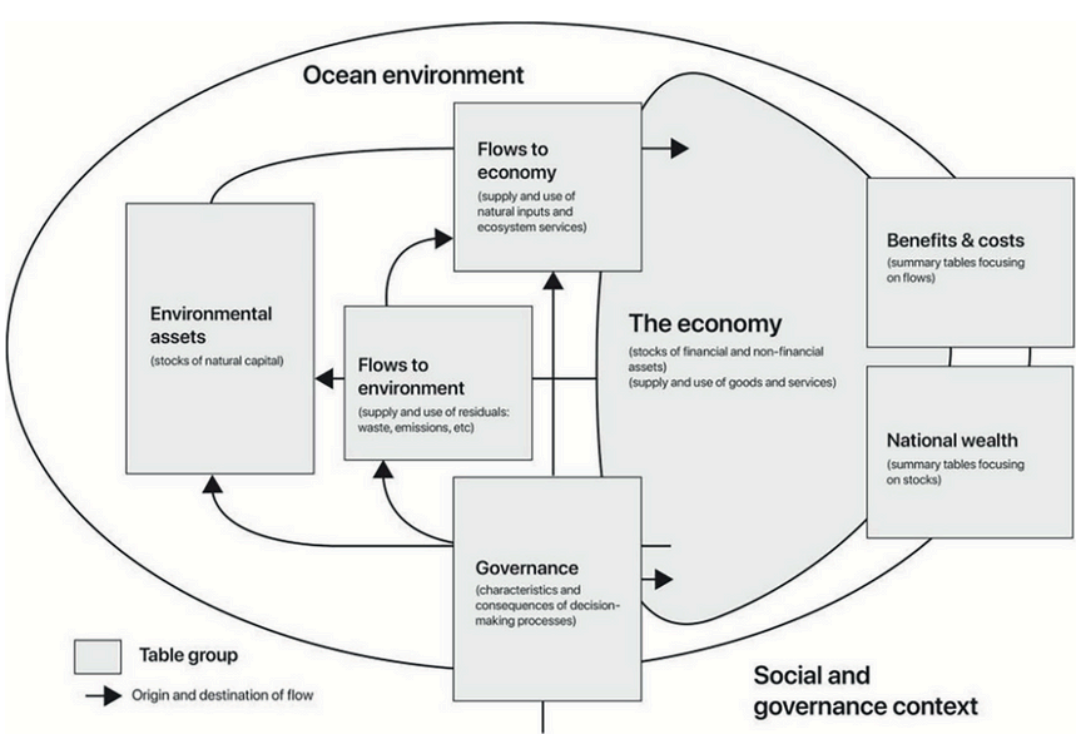

Figure 4.
The Ocean Accounts Framework ([23], p. 28).

The Ocean Accounts Framework, depicted in **Figure 4** includes both a social and governmental context, showing the interrelationships between the two ([23], p. 28, [24]). These include involving Ocean assets (natural capital); flows to economy (Ocean services, including goods); flows to environment (residuals including ecosystem impacts); the Ocean economy and the economy; governance; combined presentation (recording a "report card" of summary information, physical quantities, monetary value, and/or qualitative status) and indicators concerning the flows of benefits and costs (the latter broadly defined as maintenance and restorations costs, disservices and externalities) between the Ocean environment and the economy; national wealth; and stock of Ocean wealth (environmental assets and economic and financial assets).

The information recorded on **Figures 2**–**4** and on **Table 3** is intended to support broad decision-making when compiled on a regular basis including strategic development planning of the Ocean or "blue" economy; management of Ocean space of protected areas, marine spatial planning and integrated coastal zone management; finance and investment related to the Ocean; and Ocean analyses, monitoring, and assessment [23, 25].

3. The UN Decade of Ocean Science for Sustainable Development

The vast expanse of the marine environment, Earth's largest domain, plays a crucial role in stabilizing climate and sustaining life on our planet, with far-reaching implications for human well-being. In 2015, the UN shared the preliminary findings of the *First Global Integrated Marine Assessment* (First World Ocean Assessment, FWOA), which revealed significant degradation in much of the Ocean, noting losses in the structure, function, and benefits from marine ecosystem services. The assessment addressed ten main themes: (1) climate change and related changes in the atmosphere; (2)overexploitation of marine living resources; (3) food security and food safety; (4) changes in the patterns of biodiversity; (5) pressures from increased uses of Ocean space; (6) threats from increased pollution; (7) effects of anthropogenic (human) impacts; (8) inequalities in the distribution of benefits from the Ocean; (9) the importance of coherent management of human impacts on the Ocean; and (10) delays in implementing measures and solutions to address known problems ([26], pp. 7–10).

The findings of the FWOA led to the 2017 UN General Assembly declaration of the *Decade of Ocean Science for Sustainable Development* as an essential component of the 2030 Agenda. This initiative, referred to as the Ocean Decade, spans from 2021 to 2030, and aims to mobilize global efforts to reverse the decline in Ocean health and unite stakeholders worldwide under a shared framework. It calls for robust scientific research to effectively assist countries to improve conditions for sustainable development of the Ocean. The Ocean Decade is unique in comparison to other global initiatives focusing on Ocean science since it covers all disciplines within the field ([27], p. 3).

The UN designated the United Nations Educational, Scientific, and Cultural Organization (UNESCO) to facilitate implementation activities and ensure that the Ocean Decade benefits from international scientific expertise, partnerships, and coordination capabilities. UNESCO's Intergovernmental Oceanographic Commission (IOC) plays a key role in coordinating the Decade's preparatory processes, working collaboratively with the global Ocean community to plan activities and research in Ocean science and technology throughout the Decade. The IOC coordinates research programs, services, and capacity-building for Ocean observations, hazard mitigation, tsunami warnings, and marine spatial planning, among other critically important

initiatives, with guidance from the Ocean Decade Advisory Board, an international group of experts and leaders in Ocean science, policy, and management.

The Ocean Decade launched on 1 January 2021, after four years of strategic international planning facilitated by the IOC and guided by the vision statement *The science we need for the Ocean we want* [28]. This tagline summarizes the fundamental idea that scientific knowledge and comprehension of the Ocean are critical to attaining the envisioned state of the Ocean, emphasizing the role of science to inform policy, action, and sustainable development initiatives to protect the Ocean's health and resources for current and future generations.

The Decade's mission, to "catalyze transformative Ocean science solutions for sustainable development, connecting people and [the] Ocean" accentuates the importance of ensuring the well-being of both humanity and marine environments through impactful Ocean research and information dissemination. Educating both civil society and government officials to change policy and actions based on scientific knowledge is at the core of the Ocean Decade.

3.1 Ocean Decade Outcomes

The 'Ocean we want' for a sustainable future at the end of the Decade is represented by the following seven overarching Decade outcomes ([29], pp. 4–5):

1. A clean Ocean where sources of pollution are identified, reduced, or removed.
2. A healthy and resilient Ocean where marine ecosystems are understood and managed.
3. A productive Ocean supporting sustainable food supply and a sustainable Ocean economy.
4. A predicted Ocean where society understands and can respond to changing Ocean conditions.
5. A safe Ocean where life and livelihoods are protected from Ocean-related hazards.
6. An accessible Ocean with open and equitable access to data, information, and technology and innovation.
7. An inspiring and engaging Ocean where society understands and values the Ocean in relation to human well-being and sustainable development.

The success of the Ocean Decade relies on global involvement of scientists to engage in groundbreaking research, make recommendations for innovative solutions, and collaboratively address pressing challenges for the sustainable well-being of our Ocean and our planet. At its core, the involvement of youth and Early Career Ocean Professionals (ECOP) is imperative, as the dynamic perspectives they contribute will impact the future of Ocean conservation and sustainable practices. Integration of generational perspectives merges innovative thinking with wisdom and experience, fostering effective succession planning and enabling a more comprehensive examination of long-term implications and sustainability at broader levels encompassing all civil society.

The Ocean Decade serves as a catalyst for collective commitments to promote Ocean sustainability now and into the future. It empowers scientists to gather climate data, leverage technological advancements, foster international collaborations, raise awareness of critical issues, and educate the public, increasing Ocean literacy on a worldwide scale. These activities enable the design and implementation of effective mechanisms to deepen our understanding of the Ocean, and consequently, develop

sustainable solutions for Ocean-based development. By disseminating scientific breakthroughs globally through the Ocean Decade network, scientists have the ability to shape policies and empower businesses, governments, and civil society to adopt sustainable practices in their everyday activities.

3.2 Ocean Decade Action Framework

The Ocean Decade facilitates strategic planning and involvement in scientific research, with a focus on climate as the central component. This collaborative approach includes experts in coastal zone management, marine spatial planning, aquaculture and fishery management, disaster risk reduction, adaptation mitigation and climate services, as well as governance to create policies that ensure global peace and security. The IOC and its partners played a significant role in shaping SDG 14, *Life Below Water* [11], which focuses on conserving and sustainably using Ocean, sea, and marine resources for sustainable development. The Ocean Decade Action Framework consists of three objectives and ten challenges aimed at inspiring action from the scientific community [30].

Decade Objectives

1. Identify required knowledge for sustainable development.
2. Generate comprehensive knowledge and understanding of the Ocean.
3. Increase the use of Ocean knowledge.

Decade Challenges

1. Understand and beat marine pollution.
2. Protect and restore ecosystems and biodiversity.
3. Sustainably feed the global population.
4. Develop a sustainable and equitable Ocean economy.
5. Unlock Ocean-based solutions to climate change.
6. Increase community resilience to Ocean hazards.
7. Expand the Global Ocean Observing System (GOOS).
8. Create a digital representation of the Ocean.
9. Develop skills, knowledge, and technology for all.
10. Restore society's relationship with the Ocean.

The global challenges were identified through a consultive process facilitated by the UNESCO IOC, and involve global stakeholders including scientists, policymakers, non-governmental organizations (NGOs), and the private sector. The objectives of the global challenges contribute significantly to the UN Sustainable Development Goals (SDGs). The 17 SDGs, with their natural intersection with one another, are deeply interrelated with the Decade Challenges (see **Figure 5**).

3.3 Decade Actions

The Decade Challenges serve as 'calls to action' to the international scientific community to develop initiatives, projects, and activities that improve scientific understanding of the Ocean, promote sustainable use of Ocean resources, and enhance international cooperation and collaboration [24]. These actions will continue to be the focus over the next six years to meet the Decade's challenges, and their results will

Figure 5.
Decade challenges ([31], p. 10).

be communicated widely through strategic and multi-faceted approaches via the UN General Assembly and its Member States.

The Ocean Decade seeks to generate the scientific knowledge, infrastructures, and partnerships necessary to inform policies through global and region planning meetings. To achieve this, all actors need to come to the table. This includes scientists, academia, policy makers and managers, civil society and non-governmental organizations, businesses and private sectors, donors, and foundations, and of course, our youth. To move from "the Ocean we have" right now to the "Ocean we want" in 2030, a multistep implementation process involving three non-linear, overlapping steps has been established by the IOC.

- First, identify the knowledge that is required for sustainable development.
- Second, gather data, information, and knowledge for the development of a comprehensive understanding of the Ocean, its components, and its interactions.
- Third, use the generated knowledge and understanding of the Ocean to deploy solutions for sustainable development.

The Ocean Decade call to action inspires marine scientists and oceanographers studying all aspects of the Ocean to set specific goals as an effort to work together to contribute to a global understanding of marine environments and anthropogenic impacts on the Ocean, and to develop strategies for sustainable Ocean management. Audrey Azoulay, UNESCO Director-General, proclaimed, "How can we succeed in protecting the Ocean when we know so little about it? Only 20% of the seabed is mapped. We need to go further and mobilize the international community so that at least 80% of the seabed is mapped by 2030" [32].

In response to this challenge, UNESCO made a grand announcement at the One Ocean Summit in 2022 stating that through the collaborative actions of the Ocean Decade, at least 80% of the seabed will be mapped by 2030, compared to the 20% that has currently been recorded. The Ocean Decade places a high priority on developing a collaborative and international Ocean data management system, given that substantial parts of the global Ocean remain inadequately monitored.

The High-Level Panel for a Sustainable Ocean Economy endorsed this vision and further stressed the importance of collaboration in the Ocean Decade to share Ocean-related data through an open and equitable digital ecosystem [33]. As explained by Dr. Richard Spinrad, Under Secretary of Commerce for Ocean and Atmosphere and NOAA Administrator, "the *New Blue Economy* is a knowledge-based economy, looking to the sea not just for extraction of material goods, but for data and information to address societal challenges and inspire their solutions" ([34], para. 2).

4.Ocean Decade Call to Action

Vladimir Ryabinin, Assistant Director General (ADG) of UNESCO in charge of the IOC, proposed, "By 2030, we will put in place a global monitoring tool, which will report annually on the progress of the mapping and identify remaining gaps. This global seabed map will be one of the legacies of the UN Decade of the Ocean" [35]. According to the 2022 State of the Ocean Report, "The current Ocean observing system embraces around 10,000 Ocean observing platforms, with some 84 countries contributing to the system. … The observing system provides essential data and products to weather, climate and Ocean forecasters, maritime commerce, fisheries and coastal communities. However, there are major gaps in coverage and the system is not currently able to provide data where it is most needed, namely in areas with high biodiversity and intense human pressures" ([32], pp. 10–11). Organizations, governments, and individuals around the world are responding to the Ocean Decade call to action for Ocean conservation and sustainable management of the Ocean. This involves developing an "all of society approach" in a manner that strengthens the science-policy-society interface; working within a framework to not only engage in data collection, but also produce recommendations and engage in the implementation of potential solutions to challenges uncovered through the research process. An example of one such Ocean Decade research initiative follows.

4.1 Spotlight on an exemplar Ocean Decade initiative

The Global Ocean Ship-based Hydrographic Investigations Program (GO-SHIP) is an international initiative investigating long-term (decadal) changes in Ocean heat content, carbon uptake, acidification, circulation, and other parameters throughout

the global Ocean [36]. Fifteen nations are represented by the GO-SHIP scientific committee, with nineteen nations contributing ship time. GO-SHIP unites researchers specializing in physical oceanography, the carbon cycle, marine biogeochemistry, and ecosystems, along with other stakeholders involved in hydrographic data gathering. Additionally, GO-SHIP research cruises provide training and capacity building opportunities for ECOPs, including undergraduate and graduate students in oceanography. As a result, the program contributes to the next generation of marine scientists and broadens the availability of real-time data that ensures fit-for-purpose provision of calibration data through collaborations with partner networks and the global oceanographic community. It also focuses on the development of new data products driven by stakeholder needs and promotes innovation considering data-based solutions.

GO-SHIP is a part of the Global Climate Observing System (GCOS) sponsored by the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission of the United Nations Education, Scientific and Cultural Organization (IOC-UNESCO), the United Nations Environment Programme (UN Environment), and the International Science Council (ISC). GO-SHIP contributes to the Global Climate Observing System (GCOS), which conducts periodic evaluations of the state of worldwide climate observations in the atmosphere, on land, and in the Ocean, and provides recommendations for enhancement of research activities. Expert panels within GCOS are responsible for upholding the definitions of "Essential Climate Variables" (ECVs), crucial for systematically monitoring the Earth's evolving climate ([37], para. 2). The observations endorsed by GCOS play a vital role in addressing climate research challenges and form the foundation for climate services, as well as measures related to adaptation and mitigation. In addition, GO-SHIP is a major contributor to the World Climate Research Program's (WCRP) Climate Variability and Predictability Experiment (CLIVAR) and the International Ocean Carbon Coordination Project.

As an endorsed initiative of the United Nations Ocean Decade, *GO-SHIP Evolve*, aims to enhance the collection of biological and ecosystem data, revealing trends and variability in crucial indicators of Ocean health [38]. Of particular importance, this initiative conducts comprehensive water column measurements along designated hydrographic transects across the world's Ocean with the aim of investigating temporal changes in physical and hydrographic conditions. Information gathered during GO-SHIP research cruises plays a vital role in monitoring deep Ocean parameters, specifically those below a depth of 2 km. This segment of the Ocean, constituting more than half of the total Ocean volume, remains largely inaccessible to researchers except through ship-based hydrography.

As a result, the program contributes to a universally coordinated network of continuous hydrographic sections, supporting the broader global Ocean/climate observing system through coast-to-coast or coast-to-ice research transects. **Figure 6** shows the GO-SHIP reference sections consisting of 55 core lines strategically positioned to track long-term trends and variations in oceanic conditions. Although not all transect lines are currently occupied, they represent key pathways for comprehensive oceanic monitoring, serving as important reference points for future research endeavors and facilitating a deeper understanding of the complex interactions within the global Ocean system. These core lines enable scientists to assess changes in temperature, salinity, oxygen levels, and other critical parameters over time, helping to identify emerging patterns and trends that inform climate models

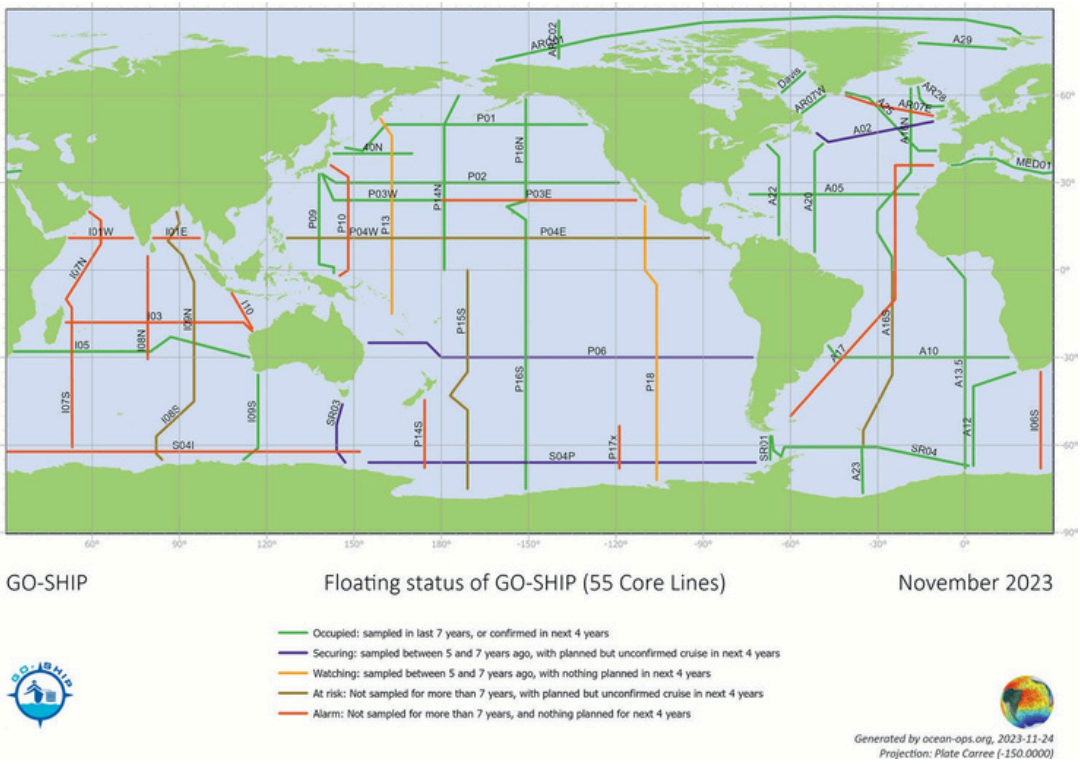

Figure 6.
GO-SHIP reference sections https://www.go-ship.org/RefSecs/goship_ref_secs.html.

and support informed decision-making regarding Ocean conservation and management strategies.

The GO-SHIP program provides invaluable insights into the profound changes occurring in our Ocean. By meticulously collecting and analyzing data from some of the most remote and inaccessible regions of the Ocean, GO-SHIP contributes crucial information to our understanding of how climate change is reshaping marine ecosystems. These data not only enhance our ability to predict future climate scenarios but also inform policymakers and stakeholders worldwide, guiding the development of effective strategies for mitigating the impacts of climate change and preserving the health of our Ocean for generations to come.

Addressing Ocean Decade Challenge 7 (expand the global Ocean observing system) and Challenge 8 (create a digital representation of the Ocean), GO-SHIP contributes to global monitoring, mapping, and identification of observational gaps throughout the global Ocean. GO-SHIP facilitates multinational voyages and shared facilities, fosters training opportunities, and accelerates the utilization of knowledge and multinational capacity, encouraging contributions from a wider array of countries [39]. A description of a GO-SHIP research cruise recently completed follows [40].

4.2 GO-SHIP A13.5: 2024

GO-SHIP A13.5 is a decadal hydrographic long-line research cruise occupying the 0E meridional line in the South Atlantic Ocean. Conducted aboard the R/V Marcus G. Langseth, a 235-foot (71.6 m), 3834-gross ton research vessel operated by Columbia University's Lamont-Doherty Earth Observatory (LDEO) on behalf of the NSF, the 2024 mission was led by scientists from NOAA's Pacific Marine Environmental

Laboratory (PMEL) and Earth and Space Research (ESR). Data gathered along the A13.5 follows cruises along the same transect in 1983/84, 1995, and 2010. Analyses and comparisons to past findings will provide insight into how this area in the south- eastern Atlantic is changing due to anthropogenic carbon emissions. **Figures 7** and **8** provide geographic views of the cruise track.

The recent re-occupation of the A13.5 transect (Ghana to Bouvet Island, February-March 2024) contributed to a universally coordinated network of continuous hydrographic sections, thereby enhancing the broader global Ocean/climate observing system. The western margin and southern limit of the South Atlantic Ocean have been significantly impacted by anthropogenic carbon (Cant) uptake, as shown by a Cant column inventory change in the region that was higher than the global mean storage rate [41]. Predictions have warned that aragonite undersaturation will occur in the next two decades along the eastern margin if anthropogenic changes maintain the present trend and have recommended more extensive monitoring in the eastern margin of the South Atlantic to identify the extent to which ecosystems health, marine life, and societies will be affected in the future.

The 2024 decadal investigations of the A13.5 transect were overdue as this line was delayed due to COVID-19. Since CTD (conductivity, temperature, and depth) instrumentation is the primary tool used for determining the physical properties of sea water [42, 43], these data are needed to continue monitoring this area. The CTD instrumentation detects how the conductivity and temperature of each water sample taken have changed relative to depth since 2010. Additionally, 2024 data will provide information about changes in the physical, chemical, and biological properties of the water column since 1983/1984, and further document changes in Ocean heat content, carbon uptake, acidification, circulation, and other parameters of interest in the southeastern Atlantic Ocean. Global CO2 and climate variability programs can use these data to complement their research on an international scale.

Figure 7.
Google Earth depiction of the 2024 GO-SHIP A13.5 cruise track.

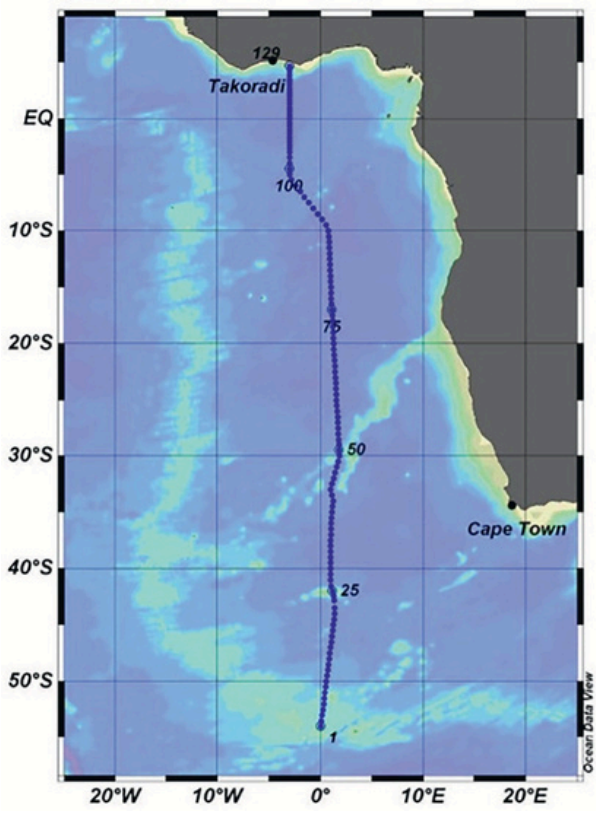

Figure 8.
GO-SHIP 2024 A13.5 Transect https://usgoship.ucsd.edu/2024/03/23/weekly-reports-from-a13-5/.

The 2024 A13.5 science team represented 14 different organizations, and included undergraduate and graduate-level oceanography students, resulting in members of the next generation of Ocean scientists becoming trained and engaged in this decadal initiative, ultimately growing the ECOP network. Additionally, to further expand education and outreach efforts to K–12 teachers and their students, scientists onboard the ship partnered with the Adopt-a-Float program to inspire and educate students about global Ocean biogeochemistry and climate change, creating a powerful opportunity for students of all ages to learn about the research underway by naming and tracking BGC (biogeochemical) floats [44]. All data collected have been made freely available by the Global Ocean Biogeochemistry Array (GO-BGC) Project funded by the National Science Foundation, Division of Ocean Sciences (NSF OCE 1946578) and by the Argo Program, which is part of the Global Ocean Observing System) and the national programs that contribute to it (http://www.argo.ucsd.edu).

5. Conclusion

More than 80% of the Ocean remains unexplored, yet human well-being is dependent on the activity beneath the waves [45]. Considering the Ocean's role in sustaining us through nourishment, climate regulation, and the production of over half of the world's oxygen, alongside its capacity to absorb 50 times more carbon dioxide than our atmosphere, it is clear why the United Nations (UN) prioritized the Ocean in its 2015 mandate, *Transforming our World: The 2030 Agenda for Sustainable Development.*

Reversing the current decline in Ocean health and educating diverse stakeholders, including all sectors of civil society, is a clear priority of the 2030 Agenda, implemented as a response to high level reports and actions issued by the United Nations General Assembly (UNGA) for more than 65 years (from 1958 to 2024). These initiatives included groundbreaking resolutions, declarations, and conventions such as the *Global Framework for Ocean Governance* established by the UN Convention of the Law of the Sea in 1982, the 2003 UNGA *Resolution 57/141* which initiated the first process for global reporting and assessment activities of marine environments worldwide, along with the 2010 *First World Ocean Assessment* that gathered data for a period of nearly five years, resulting in the *Global Ocean Science Report 2020: Charting Capacity for Ocean Sustainability* which called for a "comprehensive and holistic digital representation of the Ocean, including a dynamic Ocean map, allowing the matching of data to needs by multiple stakeholders" ([46], p. 225).

Importantly, the 2030 Agenda led to the UN proclaimed Decade of Ocean Science for Sustainable Development (2021–2030), providing a convening framework for scientists, stakeholders, diverse segments of civil society, and governments at all levels to collaboratively build awareness about the severe and alarming state of our Ocean and take action to mitigate further destruction of our global marine ecosystems. The Ocean Decade, managed by the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific, and Cultural Organization (UNESCO), prominently emphasizes the interdisciplinary nature of the 17 UN Sustainable Development Goals through Goal 14, which focuses on *Life Below Water* [47]. Through the development of scientific knowledge leading to a more comprehensive understanding of the Ocean, Goal 14 aims to deeply embed Ocean literacy into all aspects of society through the sharing of scientific evidence and collaborative management strategies. This is particularly important since the Ocean is the primary source of a substantial portion of the global economy, which is crucial in industries such as tourism, fisheries, international shipping, and transportation.

The underlying connections that link Ocean sustainability with sustainable blue economies, creates a set of shared societal goals to achieving a cleaner, more data transparent, and safe Ocean [28]. The primary goal of the Ocean Decade is to develop data-driven solutions that address the ongoing challenges and issues impacting our Ocean, and consequently inform and contribute to the development of policies, technologies, and strategies that support the growth of the New Blue Economy while ensuring responsible use and conservation of Ocean resources for the future. The transformative potential of engagement within an Ocean Decade action prepares ECOPs for future multidisciplinary research activities, provides valuable experiences communicating data-based finding on a global scale, and holds great potential to change behaviors within all sectors of civil society through broad-scale communications, dissemination of valuable research findings, and enhanced Ocean literacy worldwide.

This chapter highlighted GO-SHIP Evolve, one example of a multitude of Ocean Decade research initiatives. GO-SHIP contributes to the "multistakeholder, multicomponent digital Ocean ecosystem" described in the 2020 *Global Ocean Science Report* ([46], p. 225) through its focus on global monitoring, mapping, and identification of observational gaps throughout the global Ocean. Its current scope is concentrating on emerging possibilities for the fourth decade of GO-SHIP surveys in novel scientific domains due to evolving scientific questions, technology, and research needed to monitor and protect the world's Ocean.

The time is now to engage in research contributing to the overarching Ocean Decade goal of achieving sustainable Ocean management in support of the New Blue Economy by 2030; contributing to the "*Science We Need for the Ocean We Want*." We cannot wait another 65 years to begin seeking solutions to resolve the critically poor condition of our world's Ocean. Governments and international organizations around the world rely on research-based data to develop policies and regulations that can protect the Ocean. Join the Ocean Decade today. Marine scientists must help civil society to better understand marine ecosystems, including their biodiversity, dynamics, and interdependencies, as understanding the significance of these data are essential to making informed decisions about conservation and sustainable development of our Ocean, mitigation of anthropogenic threats, and raising awareness of the importance of Ocean conservation [48].

For more information about the Ocean Decade, see: https://oceandecade.org/sign-up/.

For information about the GO-SHIP research activities, see: https://usgoship.ucsd.edu/.

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