HARNESSING MARINE OPEN DATA SCIENCE

FOR OCEAN SUSTAINABILITY IN AFRICA, SOUTH ASIA, AND LATIN AMERICA

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ABSTRACT. One of the biggest barriers to conducting ocean science around the globe is limited access to computational tools and resources, including software, computing infrastructure, and data. Open tools, such as open-source software, open data, and online computing resources, offer promising solutions toward more equitable access to scientific resources. Here, we discuss the enabling power of these tools in under-resourced and non-English speaking regions, based on experience gained in the organization of three independent programs in West African, Latin American, and Indian Ocean nations. These programs have embraced the "hackweek" learning model that bridges the gap between data science and domain applications. Hackweeks function as knowledge exchange forums and foster meaningful international and regional connections among scientists. Lessons learned across the three case studies include the importance of using open computational and data resources, tailoring programs to regional and cultural differences, and the benefits and challenges of using cloud-based infrastructure. Sharing capacity in marine open data science through the regional hackweek approach can expand the participation of more diverse scientific communities and help incorporate different perspectives and broader solutions to threats to marine ecosystems and communities.

INTRODUCTION

Recent decades have seen increasing local and global challenges in marine environments such as ecosystem degradation, overfishing, and climate change-related impacts to coastal communities. Addressing these multifaceted issues requires a scientifically robust understanding of ocean data, which has become increasingly complex and voluminous. Despite a parallel growth of technical capability for handling large ocean data, one of the biggest barriers to conducting science and identifying science-based solutions around the globe remains the limited access in many places to computational tools, including software, computing infrastructure and data, and appropriate training materials (Miloslavich et al., 2019; Arbic et al., 2024; UNESCO-IOC, 2024). As the volume of scientific data continues to expand rapidly, these limitations will be particularly challenging for scientists from low- and middle-income countries and non-English speaking communities (e.g., Nyadjro et al., 2022). The UN Decade of Ocean Science for Sustainable Development (2021–2030) has emphasized the importance of overcoming this barrier by designating one of the 10 Ocean Decade challenges to be the sharing of skills, knowledge, and technology for all, including a recommendation specifically targeted at underrepresented groups via grassroots capacity development efforts (Arbic et al., 2024).

To help address these inequities, there is growing momentum in the scientific community to run hackweek-style events to train scientists in data science tools and methods applied to specific domains. A hackweek is an intensive event that is typically grounded on open-source software and open data and that blends structured pedagogical sessions, including lectures and hands-on technical tutorials, with less structured group project work (Huppenkothen et al., 2018; Falk et al., 2024; Rokem and Benson, 2024). By combining these learning models with a spirit of openness and collaboration, a hackweek excels at increasing knowledge, providing hands-on coding and data access experience, and opportunities to collaborate and build strong networks with others. In the marine sciences, the OceanHackWeek (OHW) initiative has advanced this approach and engaged over 400 participants from all continents since 2018 through annual in-person, virtual, and hybrid events (Mayorga et al., 2022; https://oceanhackweek.org).

A core value of hackweeks is emphasis on open-source software, reproducible research, and provision of appropriate tools alongside open science principles, including open data. The concept of open science is that the entire scientific process is made transparent and accessible, including all scientific data, tools, and publications. The open science movement has gained momentum in recent years to address a lack of equity and inclusivity in science, as well as the scientific reproducibility crisis (Gentemann, 2023; Fredston and Lowndes, 2024).

In this paper, we discuss hackweeks specific to ocean and marine sciences.

Ocean-specific hackweeks are important due to the unique features of ocean and marine data types (e.g., very large, multi-dimensional datasets and marine-specific variables) and specialized analysis methods that require specific software packages and technical knowledge bases. During a hackweek, the lectures are often generally applicable to ocean science workflows, while the projects allow for more in-depth learning on a specific ocean science research topic. The topics are chosen based on instructor expertise and participant interest, and range across many different fields of oceanography. The project topics are often not advertised before the event, as they are considered secondary to the computational skills that participants gain irrespective of their projects' marine applications.

In this article, we share three case studies of hackweek-style events, all with similar goals of exchanging knowledge in computational ocean science for underserved communities across many different low- and middle-income countries. Comparable case study details are listed in Table 1, and photos from each event can be found in Figures 1–3. In the final section, we discuss the shared lessons learned and remaining challenges across all three programs.

TABLE 1. Program, participant, and instructor information for the three case studies.

		COESSING* Coastal Ocean Environment Summer School In Nigeria and Ghana	**OHWe** OceanHackWeek en Español	**ITCOocean Hack2Week** Training Course & HackWeek On Machine Learning Based Species Distribution Modeling
PROGRAM DETAILS	**Website**	https://coessing.org	https://intercoonecta.github.io	• https://hackweek-itcoocean.github.io/2023-Hackbook/ • https://incois.gov.in/ITCOocean/itco097.jsp
	Language	English	Spanish	English
	Target region	West Africa	Latin America	Indian Ocean nations
	Location	Alternates between Accra, Ghana & Lagos, Nigeria; some years have virtual components	Virtual, with a limited hybrid pilot in 2022 (in person in Peru)	Hyderabad, India
	Length	1 week	1 week main event, complemented by shorter events	2 weeks
	Dates	Held annually in July/August	Varying (Aug 2022, Mar 2023, Jul/Oct/Nov 2024)	11–22 September
	Start year	2015 (Python open-source computing introduced 2018)	2022	2023
	Cost to attend	Free, including accommodation and food. Participants must fund their own travel to host location	Free	Free. Accommodation and food at nominal rates were provided. Participants must fund their own travel to host location
	Registration required	Yes. Involves a selection process for main event	Yes. Involves a selection process for main event	Yes
PARTICIPANT DETAILS*	**Prerequisites**	None	None, but participants are expected to demonstrate engagement in marine sciences	None, but participants are expected to have fundamental knowledge of marine ecology
	Number per event	20	10–50	58
	Career stage	Undergraduate to mid-career	Undergraduate to mid-career	Early career, including graduate students
	Countries represented	Ghana, Nigeria, Benin	16 countries from Latin America and Spain	Bangladesh, Ghana, India, Mozambique, Nigeria, Sri Lanka, Uganda, Myanmar
	Prior programming and Jupyter notebook knowledge	Nearly all are beginners, though each year there are a growing number with basic knowledge. Only past participants had familiarity with Jupyter notebooks	None to substantial, including Jupyter, Python, R, and other languages	None to advanced experience. Those who did were familiar with Python and R. No experience with JupyterHubs
INSTRUCTOR DETAILS†	**Number per event**	4	10	19 with a core team of 7
	Countries represented	Ghana, Nigeria, USA	Argentina, Australia, Austria, Belgium, Chile, Ecuador, Mexico, Nicaragua, The Netherlands, Peru, Spain, USA, Venezuela	India, South Korea, USA
	Career stage	PhD student to mid-career	PhD student to mid-career	Undergraduate to late-career

* For COESSING, participant and instructor details apply only to Python component at 2023 school.
† For OHWe and ITCOocean Hack2Week, "instructor" includes tutorial instructors, organizers, project mentors, and others providing scientific or data science assistance.

CASE STUDY ONE – Coastal Ocean Environment Summer School In Nigeria and Ghana (COESSING)

COESSING aims to build capacity in ocean science and research skills among scientists in West Africa and to connect scientists both in West Africa and elsewhere around the world. Based on participant feedback, the school format has evolved since it started in 2015 from a formal lecture and tutorial-based curriculum to a project-based approach in 2023 (Arbic et al., 2025, in this issue). Topics in 2023 ranged from physical oceanography and ocean biogeochemistry to fisheries, plastics, and conservation. One of the most popular aspects of the school has been the Python-based computer programming component, which will be the focus of the remainder of this section (referred to as "the Python component"). Although not typically referred to as a hackweek, the Python component of COESSING has functioned in a similar format to a hackweek.

A unique aspect of the COESSING Python component, compared to the other case studies presented here, is that it did not begin as a hackweek format. Rather, it evolved into a program that has ended up resembling a hackweek based on participant and instructor feedback. After three years with proprietary software, in 2018 we offered our first open-source training using the Python language. The switch was met with audible cheers from participants when they were able to plot their own datasets on their personal laptops for the first time, with software they could use beyond the summer school. With such obvious excitement, by 2019 we translated the entire curriculum into Python. Alongside the transition to Python was a move toward a more flexible, tailored approach of project-based learning, in line with the hackweek framework. In so doing, school participants were able to use open-source software to download, process, manipulate, and visualize open-access data (e.g., satellite data, Argo float measurements) and to answer pertinent issues concerning their countries' climates, oceans, and resources (Nyadjro et al., 2022). The positive feedback from the 2023 school from both participants and instructors has solidified our intention of keeping this hackweek-style approach moving forward.

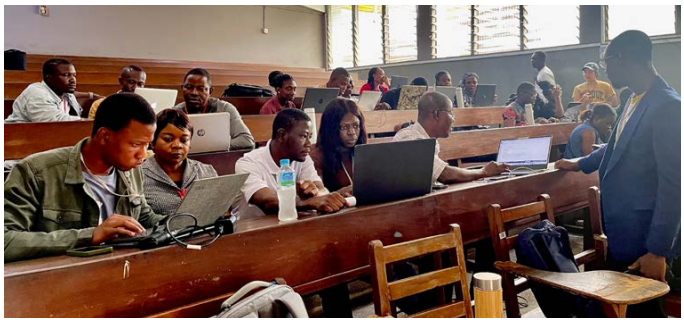

FIGURE 1. Participants, instructors, and organizers at the Python component of COESSING 2023 in Accra, Ghana.

HIGHLIGHT. AN INSPIRING STORY OF OPEN-SOURCE SOFTWARE ENABLING SCIENCE

In 2018, author Mumin Oladipo was introduced to Python computing at COESSING, quickly realized the potential uses of such a programming language, and was able to use it to set up scientific instrumentation to collect data on solar flares. Previously, he was unable to collect such data efficiently over an extended time because the monitoring software was originally distributed for Windows OS and the only data analysis software he was aware of was Microsoft Excel, which only ran on a desktop computer. While he had access to a desktop computer, its power needs exceeded what his budget could cover. After COESSING, he realized that Python was flexible enough to program a very small computer (a Raspberry Pi) to collect and analyze the data. The small computer used far less power, saving up to 80% on energy consumption, and he was able to collect data over a long period of time within his budget.

CASE STUDY TWO – OceanHackWeek en Español (OHWe)

The OHWe initiative arose out of a shared interest among Spanish-speaking OHW organizers and past participants to leverage that global program's opportunities, resources, and lessons learned in the application of open data science to oceanography and other marine fields. We adapted the well-established OHW model to serve Spanish-speaking communities through free events convening diverse participants, instructors, and organizers from across Latin America and other regions. Our objectives focus on: (1) fostering open science practices and tools that can lower the barriers of entry and adoption, (2) breaking down language barriers by offering materials and conducting events in Spanish, with localized topics, and (3) building a community that can disseminate skills in open data and open tools for marine applications.

HIGHLIGHT. BUILDING COLLABORATIONS AND LEARNING FROM ONE ANOTHER ACROSS COUNTRIES

Cotsi, Jesica, Judith, and Ruth came together for a project in the 2023 OHWe event focusing on biological indicators in upwelling regions and platform shelf areas off Latin America. The team included graduate students and a recent PhD working in universities and government agencies in Argentina, Mexico, Spain, and Venezuela, with different levels of familiarity with programming, preferences for programming language, and scientific interests. The project combined strengths in marine seabirds, deep corals, and remote sensing; used a tutorial in Spanish created for the pilot 2022 event by a Venezuelan biological oceanographer based in the United States; was mentored by a Nicaraguan marine data scientist also in the United States; and planted seeds for collaboration between the Argentinian and Spanish participants.

After a pilot event in 2022 carried out as a concurrent hybrid "satellite" of the global OHW event, OHWe received funding from Spanish agencies to conduct virtual events in Spanish for participants in Latin America. With this support, we carried out a hackweek event (2023) and two "flipped classroom" preparation events (2022, 2024) focused on basic programming skills in the two most widely used open-source programming languages for marine scientists, Python and R, and on the use of Jupyter notebooks and version control with Git and GitHub. OHWe has engaged more than 120 participants from 16 countries, developed 18 tutorials spanning basic programming to advanced topics in Python and R, and supported eight team projects facilitated by instructors and project mentors based in Latin America, the United States, Europe, and Australia (Gomez-Navarro et al., 2024).

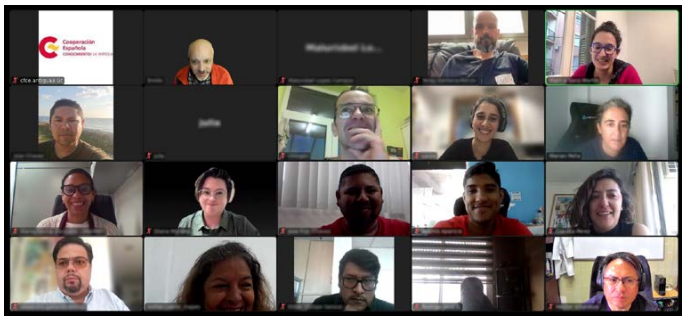

FIGURE 2. Participants, instructors, and organizers are shown in a screenshot of the OHWe 2024 hackweek event.

A common, accessible computing environment is critical to the success of a virtual program. To meet this need, OHWe reuses and customizes the cloud-based JupyterHub deployment (described in Lessons Learned below) maintained by the global OHW initiative, including localization of the interface to Spanish.

CASE STUDY THREE – ITCOocean Hack2Week

This two-week event provided training in cloud computing and data access with a focus on big Earth science remote-sensing data. It was held in September 2023 at the International Training Centre for Operational Oceanography (ITCOocean) in Hyderabad, India, and brought together 58 early career ocean scientists from Indian Ocean rim countries. The first week focused on training participants in core infrastructure and use of tools including JupyterLab and RStudio, the core scientific geospatial tools available in Python and R for remote-sensing datasets, and working with Git and GitHub. The second week was a hackweek based on participant-developed projects focused on the impacts of marine climate change in the Arabian Sea and the Bay of Bengal. ITCOocean Hack2Week relied on a cloud-based JupyterHub deployment (distinct from JupyterLab and described in Lessons Learned below) as its common computational environment. None of the participants in our course had exposure to cloud computing. About half had worked with ocean remote-sensing data and accessed data held in repositories such as Copernicus, but none had done this in a cloud computing platform. The event was supported by the global OHW 2023 event. During that event, a project team developed tutorials on marine species distribution modeling to be taught at ITCOocean Hack2week, and OHW 2023 participants participated in nightly video help sessions and taught tutorials on accessing remote sensing data with Python.

FIGURE 3. Participants, instructors, and organizers at the ITCOocean Hack2Week in Hyderabad, India.

A key goal of ITCOocean Hack2Week was to train students in the tools typically presented at the global OHW. Lack of experience with these resources has meant that students have difficulty taking part in hackweek opportunities. This hackweek intentionally accepted students with no experience at all and with no coding experience. A resulting challenge we encountered was that some participants found it difficult to keep up with the "walk through," hands-on tutorial format typical of hackweeks. We were able to overcome this challenge by helping students focus on their personal goals and definitions of success (via personal statements that they wrote) and providing ample time and encouragement for peer teaching and development of an esprit de corps during the event.

HIGHLIGHT. HELPING JUNIOR SCIENTISTS FIND CONNECTIONS AND COMMUNITY

Nani was a young graduate student who came to the hackweek alone. He did not know anyone. He had an interest in sea turtles and had some nesting field data. He had no coding skills whatsoever. But during the hackweek, his experience epitomized the special kind of peer support and camaraderie that emerges during these events. He was helped by everyone from a full professor to most junior participant. His parting words in the hackweek WhatsApp chat group captures what these immersive and supportive experiences mean to young students. *I am Short of words, I want to replay past three weeks of life on loop, where I bumped into world of mesmerizing souls...I miss...amusing discussions, unintended long walks, stupid jokes, trying to learn new languages, early morning online sessions, teaching, guidance, and seminars. Relationships in the canteen, the INCOIS lovely gardens, the paradise biriyanis, late-night strolls, foolish conversations, weekend getaways, failures, learnings, the oldest children, the youngest seniors, and everyone's advice. Thank you for everything.*

LESSONS LEARNED

Importance of Open Resources

Across all three initiatives, open-source software and open data were critical to fostering international capacity and collaboration in ocean science (Miloslavich et al., 2019; Arbic et al., 2024). By enabling researchers and resource managers globally to freely use, share, and modify the tools critical to their data-intensive work, these open resources promote inclusive and collaborative practices. This is particularly important for researchers from under-resourced regions and backgrounds, who often face severe budget limitations. Data from open repositories enable both access to environmental data about the participants' regions and accessible opportunities to demonstrate advanced computational methods. The value of open-source software is illustrated by the cloud-based computing platform used in each hackweek event (JupyterHub, described below) and by the COESSING program's transition from proprietary to open-source software. The use of open-source software in these hackweek events enables participants to continue to use these tools for their own work beyond the hackweek, because the software they have learned is not proprietary. Additionally, the collaborative model common in the open-source software community further connects these often underrepresented communities with the international open science community. By publicly sharing their hackweek projects, participants also contribute to the availability of open resources containing examples highly relevant to their regions and, for OHWe, in their local languages.

- LESSON LEARNED. Open computational resources equip scientists in low and middle-income countries to access the same tools and data as other scientists around the globe and can entrain them into the global open science community.

In-Person vs. Online Events

ITCOocean Hack2Week was in-person with an evening virtual component during which helpers joined in from the United States. The OHW community worked in teams located in breakout rooms, COESSING 2023 was in-person with an optional online lecture portion two weeks before the in-person event (previous years of COESSING were conducted in-person only, online only, or hybrid), and OHWe was online with one pilot hybrid event in 2022.

The takeaway from the COESSING events is that, for the West African community, in-person is more successful than fully online or hybrid. There were several reasons for this: (1) the biggest challenge was that internet connectivity and bandwidth can be extremely limited in West Africa, making video lectures followed by real-time discussions between instructors and participants or among participants very difficult; (2) online participants often find it challenging to devote the necessary time to fully participate in the event due to other life commitments (e.g., jobs, family duties); and (3) the excitement for learning and networking is much greater in an in-person event compared to online. Additionally, COESSING has found that a hybrid event requires far more effort from organizers for minimal to no benefit. Indeed, it was found that trying to integrate in-person and online participants did not work well for either cohort. COESSING has made the decision to focus on in-person events moving forward, while using online engagement (e.g., individual lectures) spread throughout the year to maintain community momentum between in-person events. The ITCOocean Hack2Week focused on in-person events for the same reasons. However, participant travel cost was a significant barrier, and we will prioritize securing travel support for future events.

Despite the issues encountered, other hackweek experiences, including OHW, have highlighted the value of either online-only or hybrid events while pointing out the distinct challenges and strategies that can help make such learning models more successful (Mayorga et al., 2022; Rokem and Benson, 2024). While originally motivated by COVID concerns and limited funding, the online-only mode for OHWe has enabled greater access to this learning experience at a regional scale for participants, instructors, and mentors who would otherwise not be able to travel, and encouraged the development of robust online resources, including videos, that can be fully used by people who did not participate in the events (Gomez-Navarro et al., 2024). Notwithstanding time zone constraints, instructors and project mentors have been attracted from across the world, enabling a broad scientific diaspora to contribute their expertise and enthusiasm together with regional scientists. It has also enabled collaborations and relationship building across many countries, based on common interests. However, as has been frequently observed, virtual participation often leads to lower engagement, a higher drop-out rate, and more challenging conditions for seeking and providing effective assistance. OHWe continues to learn from past events to improve the experience for individual participants and reduce attrition.

- LESSON LEARNED. There are distinct benefits and limitations to in-person, online, and hybrid events. While in-person events encourage greater engagement and deeper connections, online and hybrid events can provide meaningful experiences when properly managed, and their flexibility and accessibility can reach broader, more diverse communities.

Open Computing Platform in the Cloud

Cloud computing platforms are a key resource for technical training events. Our three case studies have recently used the same computing platform, a JupyterHub environment (https://jupyter.org/hub) hosted on the commercial cloud. This open-source cloud computing platform provides a browser-based, user-friendly common development environment for both tutorials and team projects, eliminating the need for software installation and

dramatically reducing learning barriers (Rokem and Benson, 2024; Sauthoff et al., 2024). While community-maintained JupyterHubs have accelerated research on climate change and other environmental challenges in upper income countries, scientists in low and middle-income countries have had little exposure to this tool.

The three case studies chose to use JupyterHub for ease of instructor setup and participant engagement, as well as its continuing usefulness for participants to apply their skills with it beyond the hackweeks. The platform delivers seamless development and execution of Python and R scripts via the open-source JupyterLab and RStudio interfaces, respectively. As these cloud-based interfaces are identical to what users encounter when they install them on their own computers, use of these programs provides both experience with computing on the cloud and familiarity with software that is widely used on personal computers. One of the goals of the ITCOocean event was to train participants in accessing Earth data in the cloud; JupyterHub deployments are common in geosciences training events (workshops and hackweeks), and lack of experience with JupyterHub results in participants not being selected for training events. The COESSING 2023 event used JupyterHub for online lectures but ran the in-person portion on participants' laptops. This required more setup time but was viewed positively by participants as they were then ready for computing beyond the hackweek and did not have to battle weak internet connection in the classroom.

To minimize the required expertise and to leverage community experience, our deployments are managed by the nonprofit 2i2c (https://2i2c.org) research and education service provider. The estimated cost of running and doing computations on a cloud-based 2i2c JupyterHub over a couple months for ~50–100 participants typically ranges from US$5,000–$10,000, depending on a number of factors (e.g., number of users, type of usage, duration of usage, scale of computations, amount of data storage). Subsequent events after the initial hackweek often incur lower costs due to one-time setup fees. Note that a skilled JupyterHub technical point-person is still required and was one of the instructors or organizers in each of the three case studies presented here.

- LESSON LEARNED. JupyterHub has some great benefits for in-person and especially online events, but also some noticeable drawbacks (listed in Table 2).

Community Building

The OHW experience highlights the importance of networking and community building as a key desired outcome for participants and instructors alike. Beyond the specific technical training, these events provide opportunities for participants to forge meaningful professional relationships and build a supportive network composed of both regional and international ocean scientists and resource managers. This sense of community has encouraged ongoing collaboration that extends beyond the hackweek and is critical for increasing diversity and inclusion in the ocean sciences community globally. In addition, the instructors' ties to the global OHW initiative entrains a broader pool of experience, resources, and people.

The community connections work in different ways across programs. OHWe has found a powerful connection in a shared spoken language that spans multiple countries with shared cultural ties and links the scientific diaspora living in non-Spanish speaking countries to the rest of the Spanish-speaking ocean science community. By having native Spanish speakers as organizers and instructors, attendees see their own communities represented in leadership roles, helping to build trust and a sense of belonging.

The COESSING and ITCOocean communities are structured a bit differently, mixing US, European, and locally based organizers and instructors, but with primarily locally based participants. Based on participant feedback from COESSING (e.g., see https://coessing.org/testimonials/), networking and working with international instructors is just as important as the networking among the West African ocean science community. Given the significance of networking to participants, the organizers of the ITCOocean event devoted 25% of the schedule to community building activities during the first week. More senior participants were tapped to give

TABLE 2. Benefits and drawbacks of using the JupyterHub cloud-based computing platform.

BENEFITS	DRAWBACKS
USER SETUP: No user setup or installation required. Users only need access to a device with a web browser.	**COST:** JupyterHub setup requires specialized cloud engineer expertise. All three case studies paid a nontrivial amount to a third party to set up and run JupyterHub.
UNIFIED ENVIRONMENTS: Instructors can tailor the software environment so that all users encounter the same environment regardless of device or location.	**LONG-TERM ACCESS:** Due to the cost, access to the JupyterHubs is removed after the hackweeks end.
DATASET ACCESS: Access to publicly available datasets in the Cloud (with certain limitations).	**INTERNET REQUIREMENT:** A stable internet connection is required, though high bandwidth is not necessary.
INTERFACE TRANSFERABILITY: Same interface and software as other platforms, including laptops, allowing for easy transfer of skills once JupyterHub is shut down.	

lectures in order to allow participants get to know them and to support the peer-learning/-teaching ethos. One example from both communities regarding the excitement of building lasting networks is the extremely active WhatsApp groups that continue between the annual events. People post about upcoming events, congratulate community members for receiving awards, and engage in other related discussions in these groups. The communities that are built across the three programs are unique and distinct, but there is a clear, strong desire from participants and instructors alike to create and maintain these professional networks.

- LESSON LEARNED. Community building and networking are among the most rewarding and lasting aspects of hackweek events.

Closing the Gap Between Participant and Instructor

Each program has embraced capacity sharing, where knowledge is exchanged across communities and not just from instructor to participant. The hackweek-style framework of hands-on and collaborative learning lends itself particularly well to this approach. Instructors act as facilitators, encouraging active engagement and discussion with participants. This approach has been extremely positive for both parties—participants feel empowered to take ownership of their projects, and instructors can learn from participants' diverse experiences and expertise. In the case of OHWe, the shared language and cultural contexts (such as popular music references) also highlight the value of learning in the participants' native language so they can readily engage in the program and ask questions (Miloslavich et al., 2019; Ación et al., 2022; UNESCO-IOC, 2024). Furthermore, program instructors are often former participants, enhancing collegiality among the two groups. For example, two of the Python instructors at COESSING 2023 had been participants at previous COESSING events. This was not only empowering for these individuals as they gained teaching experience but was also encouraging to other participants as they saw fellow West Africans become ocean science Python experts.

- LESSON LEARNED. The shared and collaborative learning model has been quite successful for participant engagement and fostering a sense of community.

Adapting to Cultural Diversity

In addition to program similarities, it is important to emphasize the diversity of participants across all three programs. Each program is tailored to communities based on geographic location or spoken language, and each has adapted to local cultural expectations. For instance, COESSING incorporates formal opening and closing ceremonies, often with local music and dance groups performing, as expected for such events in the host countries. The three programs have adapted to specific cultural expectations in order to work respectfully and fruitfully with the participating communities, embracing capacity sharing by learning from one another. For example, all programs offered a certificate upon completion, which participants often require as proof of their newly gained skills. COESSING and ITCOocean Hack2Week further presented individual certificates with a handshake and photo with a local academic official or event instructor.

- LESSON LEARNED. All three case studies found it important to tailor their events to the target communities to show respect to and maximize the benefit for participant and instructor communities.

Assessing Impact

In order to garner funding and to improve capacity sharing events, it is important to assess follow-on impacts on individual participants as well as on greater ocean science communities. The three case studies recognize this importance and run surveys of participants and instructors after each event. However, because each event is organized by ocean data scientists, there has been little focus on how to best conduct surveys and how to aptly interpret survey data. While the organizers do their best in this regard, effectively assessing impact on the participants and the greater ocean science communities is an aspect that should be given greater importance when running such events in the future.

- LESSON LEARNED. More attention should be paid to assessing the impacts of such events moving forward.

Funding

The bulk of funding for these events goes toward the JupyterHub, small stipends for organizers and (for some events) instructors, instructors' travel (for the in-person events), and local venue costs. The events rely on instructors and organizers largely volunteering their time and on participants funding their own travel (for the in-person events).

Finding sustained funding to achieve our common goal of supporting ongoing, recurring events presents an especially difficult challenge. All three of these grassroots-based programs put significant effort each year into securing funding. In particular, travel funding is critical for participants and presents an insurmountable barrier for many but is often hard to secure compared to in-kind contributions of space or time.

- LESSON LEARNED. Funding for multi-year events remains one of the biggest challenges to running capacity sharing events around the globe.

SUMMARY

We have showcased three programs that harness marine open data science to elevate the capabilities of scientists in diverse international communities, particularly those from under-resourced and non-English speaking regions. Our main goal is to share the benefits, challenges, and lessons learned from applying the hackweek capacity-sharing model in these contexts. Hackweeks function as knowledge exchange forums and can foster meaningful international and regional

connections among marine scientists across the globe. Inclusion of diverse scientific communities leads to more equitable access to the powerful capabilities in ocean data science and incorporates different perspectives on and broader solutions to threats to marine socio-ecological systems. It is vital that all communities be equipped with the appropriate technical skills, tools, and scientific networks to better understand and best address these environmental challenges and opportunities. We believe that hackweek-style programs like these will go a long way toward achieving this goal.

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