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Ocean Outreach in Australia: How a National Research Facility is Engaging with Community to Improve Scientific Literacy

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Marine systems across the globe are experiencing myriad pressures with consequences for their health, management and the industries and communities that depend on them. Critical to improved management of our oceans and coasts is effective education and communication that ultimately leads to improved societal value of the world's oceans. In Australia, the national scientific research agency, CSIRO, operates critical national research infrastructure such as the Marine National Facility (MNF), which also plays an important role in marine education, training and communication. The MNF Outreach Program seeks to strategically engage the community in marine science, identifying audience segments and developing programs, activities and content to meet their specific information needs. The program is structured around three specific audience segments: Purpose Seekers, Nurturers and Lifelong Learners. With both at-sea and shore-based activities and programs including the Indigenous Time at Sea Scholarship, CAPSTAN sea-training, Educator on Board, Floating Classroom, live ship-to-shore crosses and media and social media programming, the MNF Outreach program delivers meaningful engagement through experiential learning opportunities, rather than simply addressing knowledge deficits. As marine issues are varied and complex, marine communication and education approaches must be equally multifaceted, and a successful outreach program will have a spectrum of activities of varying resource intensity (such as cost, time and appropriately skilled personnel) which are matched to clear target audience segments. With increasing recognition of the importance of science communication in informing science literacy and policy, publicly funded national research facilities have an essential role to play by shifting from traditional research-only roles to also provide for targeted education and outreach.

Keywords: marine, outreach, education, training, ocean, engagement

INTRODUCTION

The global ocean covers 71% of the Earth surface and contains about 97% of the Earth's water (IPCC, 2019). It is our planet's largest ecosystem: stabilizing climate, storing carbon, producing oxygen, nurturing unimaginable biodiversity, and directly supporting human well-being through food, mineral, and energy resources as well as providing cultural and recreational services (United Nations, 2019). More than 40% of the global population lives within 200 km of the ocean (Visbeck, 2018). Yet marine systems across the globe are experiencing myriad pressures with consequences for their health, management and the industries and communities that depend on them.

The *United Nations Decade of Ocean Science for Sustainable Development 2021–30* (The Decade) seeks to strengthen the management of our ocean for the benefit of humanity by providing science, data and information to inform policy, and to generate scientific knowledge, underpinning infrastructure and partnerships. Critical to this capacity building is effective education and communication that ultimately leads to improved societal value of the ocean. There is a tremendous opportunity to connect ocean science more directly with societal actors by promoting integrated ocean observation and solution-oriented research agendas (Visbeck, 2018) and improving ocean literacy and education to modify social norms and behaviors (Claudet et al., 2020).

The Decade represents a key time to focus on the development of a globally coordinated, sustained, integrated and fit-for-purpose ocean observing system to support ocean science, assessment, prediction and the production of information that can inform policymakers and decision makers at all levels across local to global scales. It also provides space to more efficiently and widely promote ocean literacy as a key tool to engage society and to lever actions on the ground (Claudet et al., 2020), develop marine science research training that is more aligned with industry, government and societal needs (National Marine Science Committee, 2015) and engage more effectively with Indigenous knowledge systems.

The environment in which marine researchers operate today is increasingly diverse (female scientists represent on average 38% of the researchers in ocean science, about 10% higher than science overall), multidisciplinary (39% of ocean science facilities work across a broad range of issues) and resource intensive (numerous staff and costly equipment including ships, ocean installations and laboratories are distributed around the world comprising, for example, 784 marine stations, 325 research vessels, and more than 3,800 Argo floats) (UNESCO, 2017). Diversity in both people and discipline drives innovation and progression. However, to achieve a society that genuinely values the ocean, educates and trains expert marine practitioners and engages with a receptive community, national marine facilities need to shout about the quiet achievements of their research collaborators, communicate the impact they are generating and engage across all audience segments by developing programs, activities and content to meet the specific information needs of each.

THE AUSTRALIAN CONTEXT

Australia's marine environment is the third largest in the world, with an exclusive economic zone covering 10.2 million square kilometres (Australian Institute of Marine Science, 2018). With more than 70% of Australia's territory lying beneath the ocean (Australian Institute of Marine Science, 2018) it is home to a diverse and unique array of ecosystems and seascapes which are largely unexplored. Australian oceans are home to 11% of the world's known marine species, and support over 5,000 species of fish, and around 30% of the world's sharks and rays (Pink, 2010). The economic and conservation value of these waters is considerable as they contain valuable oil and gas fields and fisheries, as well as significant environmental assets such as the coral reefs, mangroves, sea grass beds, kelp forests and rocky reefs that are home to a diverse range of marine plants and animals (McCormick, 2020).

Australia's oceans directly and indirectly support commercial industries such as fisheries, shipping and resource extraction, and provide important revenue from recreational activities and tourism. The economic value of resources provided by the marine environment currently contributes approximately $50 billion per year to Australia's economy and is expected to increase to approximately $100 billion per year by 2025 (NMSP, 2015). Importantly, Australia's oceans and coasts also provide an estimated $25 billion worth of essential ecosystem services, such as carbon dioxide absorption, nutrient cycling and coastal protection (Evans et al., 2017). Together, this is referred to as the blue economy.

High-quality science, technology, engineering and mathematics (STEM) education is seen as critically important for Australia's current and future productivity, as well as for informed decision making and effective community, national and global citizenship (Australian Government, Department of Education, Skills and Employment, 2020). Yet there are numerous impediments to participation in STEM education and public engagement with STEM. Barriers to both the adoption and continuation of STEM education among young people include shortages of STEM qualified teachers, lack of investment in teacher professional development, challenges faced by STEM teachers to inspire their students, lack of support from school systems, limited opportunities for hands-on training of students, a dull curriculum, lack of awareness of career opportunities in STEM by both students and teachers, lack of career role models, and a perception that STEM subjects are too difficult (see Ejiwale, 2013 and Tytler et al., 2008 for reviews). At a broader level, there still exists a lack of knowledge and awareness about STEM and STEM professionals in the general community (Tytler et al., 2008) and effective public engagement is often hampered by issues such as an over-reliance on a small number of individuals, a lack of time and resources by STEM professionals, and a lack of systematic training and incentives for STEM professionals to participate in public outreach (Nature Neuroscience Editorial, 2009; Devonshire and Hathway, 2014).

In the marine sciences, Australia's National Marine Science Committee, an advisory body focused on promoting the nexus between high quality marine science and growth of the nation's

blue economy, has developed the National Marine Science Plan 2015–2025 (the Plan) to provide a decadal focus on the investment and science required to fulfill the blue economy's potential. It outlines the research, infrastructure, skills, partnerships and investment that will drive the required changes over the next ten years. With challenges including marine sovereignty and security, energy security, food security, biodiversity conservation, sustainable urban coastal development, climate change adaptation and resources allocation, the Plan proposes a number of actions. These include improved decision-support tools, models and forecasts, industry and government partnerships, national collaborations, the application of cross disciplinary skills, the funding of national research vessels, increased exploration, mapping and monitoring, and the development of marine baselines and monitoring programs.

One of the Plan's key recommendations is to "develop marine science research training that is more quantitative, cross-disciplinary and congruent with industry and government needs." While there are many world-class tertiary offerings in the disciplines relevant to the blue economy, less than 3% of Australia's higher-degree research completions between 2009 and 2013 had an explicit marine science focus (NMSP 2015) and few universities have attempted to address the mismatch between the disciplinary focus of postgraduate training and industry demand (MacKeracher and Marsh, 2019) As such, Australia desperately needs to increase the participation rate and quality of students in a number of disciplines fundamental to marine science: mathematics, statistics, physics, chemistry and Information and Communication Technology (ICT) (MacKeracher and Marsh, 2019). The Plan also highlights the responsibility of the marine science community to facilitate a public engaged with marine issues.

Australia's national science agency, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), is committed to working to discover, enhance and sustain marine ecosystems, maximize the benefits from Australia's marine territory and, as one of the world's few publicly-funded research organisations, play an important role in science education and communication. CSIRO is also uniquely placed to invest in cultural knowledge and the participation of Aboriginal and Torres Strait Islander peoples in research. As inhabitants of the continent for over 65,000 years (Clarkson et al., 2017), Aboriginal and Torres Strait Islander peoples have enduring connections and rich knowledge of Australia's marine environments. Being the first marine scientists, Australia has much to gain by creating opportunities for genuine collaboration that leverages benefit from the fusion of Indigenous and western knowledge systems. In 2013, the Australian Government released its Indigenous Engagement with Science: Towards Deeper Understandings report (Expert Working Group on Indigenous Engagement with Science, 2013) to acknowledge the significant contributions that Aboriginal and Torres Strait Islander peoples have already made to the development of science in Australia, and the urgency to communicate the continued importance of engaging Aboriginal and Torres Strait Islander peoples in science to the scientific and broader Australian community. In response, CSIRO launched its Indigenous STEM Education Project in 2014, recognizing the important contributions that Aboriginal and Torres Strait Islander peoples can make to the future of STEM industries in Australia. Coupled with its Reconciliation Action Plan (Commonwealth Scientific and Industrial Research Organisation, 2016), CSIRO is committed to investment in Aboriginal and Torres Strait Islander cultural knowledge in relation to science, and the participation of Aboriginal and Torres Strait Islander peoples in Australia's research and innovation landscape. However, it remains the case that Aboriginal and Torres Strait Islander peoples are under-represented in STEM, particularly at the university level, where 0.5% of the Aboriginal and Torres Strait Islander population have a STEM qualification, compared to 5.2% of the non-Indigenous population (Office of the Chief Scientist. 2020).

CSIRO operates the Marine National Facility (MNF), the nation's only dedicated blue-water research capability. The MNF provides a blue-water research capability to the Australian research community and their international collaborators, comprised of the ocean class Research Vessel (RV) *Investigator;* advanced multidisciplinary scientific equipment and instrumentation; a repository of marine data collected since the MNF's inception in 1984; and operational and technical personnel with the expertize required to manage an ocean-going research platform and support vessel users. The research done on MNF voyages provides important information that supports evidence-based decision-making by government, industry and other stakeholders. MNF's strategic plan includes a focus on education and training and community engagement. Over the next decade the MNF will enhance education and training programs to include training the next generation of marine researchers and technicians in collaboration with other research/operational agencies and industries and increase their focus on communicating the impact of research delivered to better connect with Australians. The MNF is committed to delivering education and training activities that encourage and develop future generations of researchers and technicians, and help Australians understand the social, economic and environmental benefits of our oceans.

THE MARINE NATIONAL FACILITY OUTREACH PROGRAM

The MNF has sought to strategically engage with the community about marine science, identifying audience segments and developing programs, activities and content to meet their specific information needs (**Figure 1**). These activities are consolidated in the MNF Outreach Program, which focuses on increasing scientific literacy through experiential learning opportunities rather than simply addressing knowledge deficits. Commencing in 2016, the program is centered around three specific audience segments.

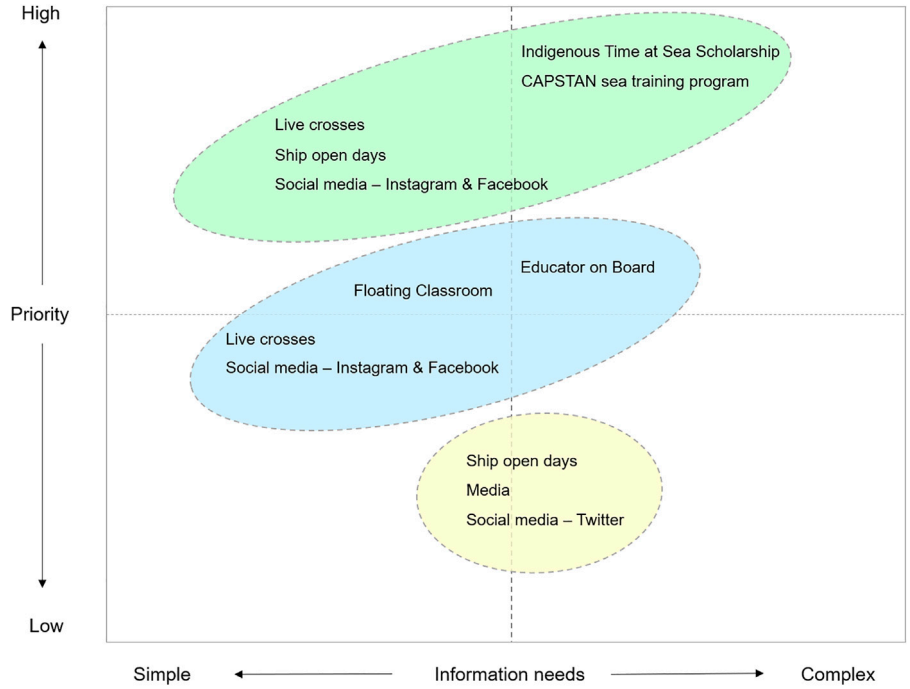

FIGURE 1 | Audience map of the MNF Outreach Program in context of target priority (*y*-axis) and information needs (*x*-axis). Audience segment groupings are represented by colored ellipses (green = Purpose Seekers, blue = Nurturers, yellow = Lifelong Learners).

Purpose Seekers

Purpose Seekers are the demographic of 13–34 year olds, encompassing Generation Z and Millennials. Purpose Seekers are typified by high school and tertiary students and those early in their career. This audience segment is seeking a future they can be excited about and have comparatively simple information needs. MNF offers several programs and activities targeted for this group (**Figure 1**).

Indigenous Time at Sea Scholarship

The Indigenous Time at Sea Scholarship (ITSS) offers Aboriginal and Torres Strait Islander university students a unique opportunity to gain experience on a world-class marine research vessel. ITSS brings students on board RV *Investigator* voyages to work alongside scientists and technicians to assist with research and gain valuable at-sea research experience. The program also aims to increase the diversity of the science teams on board voyages, which has multiple benefits.

Launched in September 2019, ITSS alumni report that the program increased their confidence and enthusiasm to study and pursue STEM careers (mean 10.0 ± 0.0 SD, N = 2), their motivation to engage with professionals from a range of STEM disciplines (mean 10.0 ± 0.0 SD, N = 2) and empowered them to encourage and inspire their peers at university and within their communities to pursue STEM studies (mean 9.0 ± 1.4 SD, N = 2). Following their involvement with the ITSS program, students have gone on to have their stories published in national media, featured as interviewees on national radio and television, and contributed to outreach activities in schools around the country thereby leveraging their experience and providing role models for other Indigenous and non-Indigenous students studying STEM.

CASE STUDY: INDIGENOUS TIME AT SEA SCHOLARSHIP SCHOLAR SOPHIE GILBEY

Alyawarr woman Sophie Gilbey was one of two students to be awarded the first Indigenous Time at Sea Scholarship. Sophie joined an 11 days voyage on RV *Investigator* studying the ocean and atmosphere of the Australian tropics and west coast between Darwin and Perth (**Figure 2**). On the voyage Sophie participated in research of plankton, sea birds and marine mammals, microplastics and meteorology. She learnt that there is a relationship with the ocean and everyday life that isn't always obvious and that it is far more complex than she realized; everything that humans do can have an impact on the ocean and as we rely on the ocean for food and regulating our climate, what we do to the oceans will ultimately affect us in the long run, it is more than just fishing and days at the beach. She firmly believes that her experience in the program has not only put her in a better position to share this message, but that she has built unique skills and is more employable as a result. Feedback from the voyage shows that other voyage participants benefited from having ITSS students like Sophie on board as she was able to share her unique experiences, perspectives and knowledge systems.

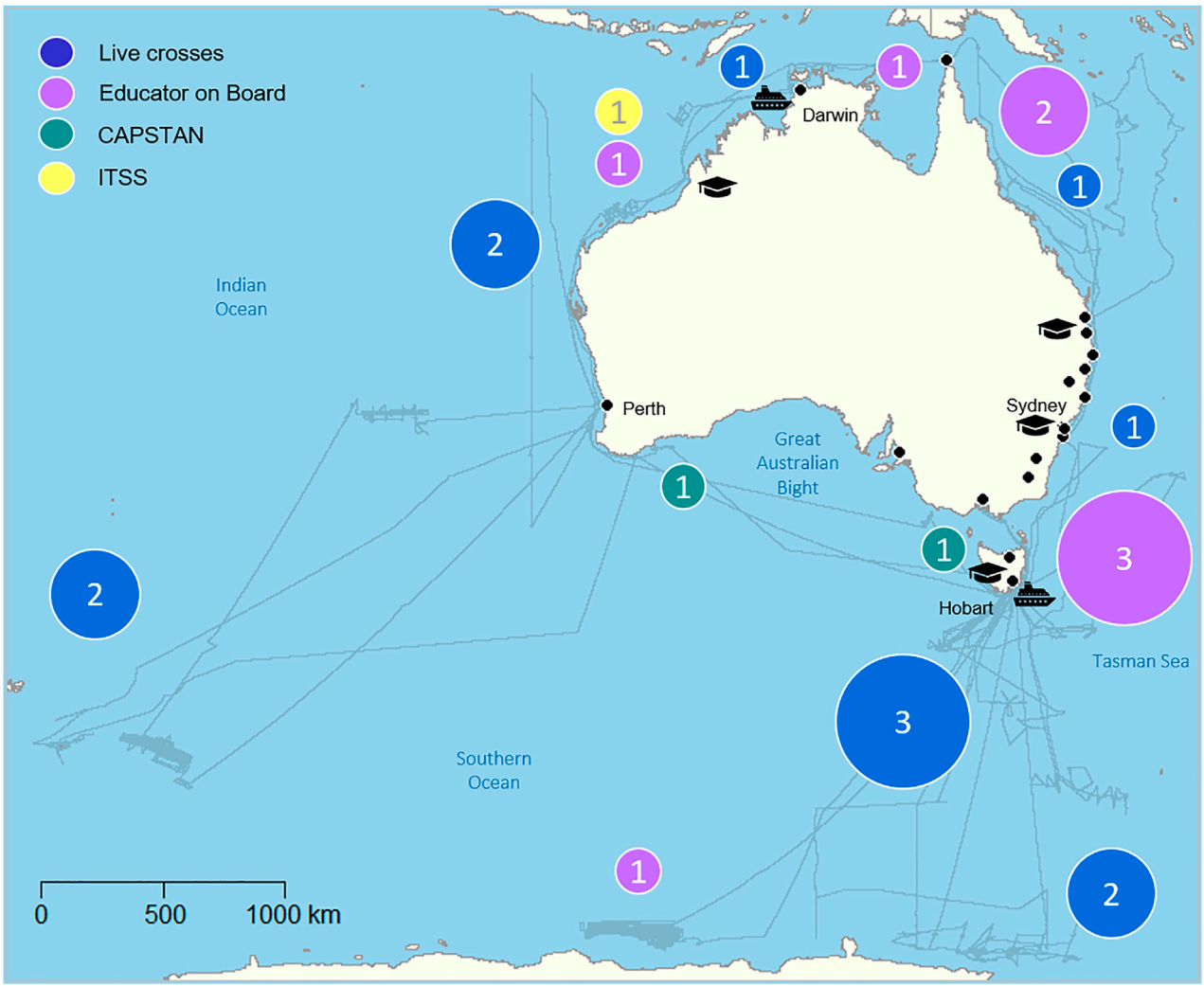

FIGURE 2 | Map of all activities undertaken as part of the MNF Outreach program 2016–20. Colored circles with numerical values represent the number of voyages hosting respective programs and activities grouped by geographic region. Voyage tracks are given in dark blue. Black circles indicate locations of audience for live ship linkups. Back pictograms represent ports that have hosted ship open days (ship) and *Floating Classrooms* (mortarboard).

Collaborative Australian Postgraduate Sea Training Alliance Network

The Collaborative Australian Postgraduate Sea Training Alliance Network (CAPSTAN) is a collective effort between MNF and Australian Universities to give tertiary students a hands-on-experience in blue water research. The program is building a network of marine researchers familiar with Australia's marine infrastructure, bringing students and marine experts from across Australia on a dedicated training voyage on RV *Investigator* each year (**Figure 2**). To date there have been 57 participants (students and trainers) from 17 Australian Universities in the CAPSTAN program who have spent 1,368 education days at sea (**Table 1A**). CAPSTAN focuses on an interdisciplinary approach to marine science with transferable skill development while promoting institutional, industrial, and generational knowledge transfer. Self-evaluations of learning conducted at the end of each CAPSTAN offering shows 93% of students improved their discipline specific skills (e.g. sediment descriptions, acoustic interpretations, sea life identification, data analysis) and 85% of students identified an improvement in their transferable skills (e.g. problem solving, critical thinking, teamwork, communication). An increase in their understanding of marine science career options was reported by 97% of student participants and all student and trainer participants indicated they would recommend the program to others. The factors the students identified as most important to facilitating their learning were related to the hands-on nature of the program, the environment on board created by the crew and the laboratory experience.

Students are not the only ones who benefit from their participation in the program, trainers also benefit from new collaborations and enhanced skills. Past trainers have written research proposals together and started projects with student

TABLE 1 | Summary statistics for the MNF Outreach Program for **(A)** at-sea programs 2016–2020, **(B)** on-shore activities 2016–2020 and **(C)** media and social media activities 2018–2020.

(A) At-sea programs

Program	Participants	Days at sea	Education days[a]	Number of universities/ schools	Gender diversity ratio (Male: Female:Other)
ITSS	2	11	22	2	0:2:0
CAPSTAN	57	24	648	17	22:35:0
Educator on board	17	150	273	17	10:7:0

(B) On-shore activities

Activity	Students/ teachers	Participants Public	Australian states/ Territories
Live crosses	3860	20 200	8
Floating classroom	271	–	4
Ship open days	1138	4733	2

(C) Media and social media

	Mainstream media		Social media snapshot	
	Items	Audience reach	Tweets	Impressions
2018/19	850+	10M+	600+	19M+
2019/20	1300+	10M+	450+	16M+

[a]*Education days = participants × voyage duration (days).*

participants from other institutions. Trainers frequently highlight that the program helped them broaden their research scope, improve their people management skills, and gain teaching experience. The ability to teach complicated concepts to students from diverse backgrounds and across career stages is a recurring theme in trainer feedback surveys. The upskilling of trainers is also beneficial to the MNF, ensuring a pipeline of experienced marine researchers with the relevant skills to form Australia's next generation of Chief Scientists and Principal Investigators.

CASE STUDY: COLLABORATIVE AUSTRALIAN POSTGRADUATE SEA TRAINING ALLIANCE NETWORK STUDENT ELISE TUURI

Flinders University then honors student Elise Tuuri was one of 20 students on the inaugural CAPSTAN voyage in 2017. The students met RV *Investigator* and a team of expert trainers from across Australia in Fremantle for a 12 days voyage across the Great Australian Bight to Hobart (**Figure 2**). A biologist by training, the voyage provided her first real dive into the breadth of disciplines involved in marine science. On the voyage she learned what it meant to live at sea, living and working within an isolated community that operates around the clock. She worked in small teams guided by the expert trainers on board to process sediment samples, identify and count marine mammals and sea birds, analyze water chemistry, and synthesize data to describe the biogeochemical processes at play in the Bremer Canyon region of the Great Australian Bight. While the region is named for the submarine canyon, for Elise and many of the other students on the voyage, the importance of that physical canyon in explaining why Bremer is known for whale watching was a level of interdisciplinary science she had not previously considered. When not busy in the laboratories, Elise learned to tie knots with the ship's crew, took a tour of the engine room, learned about life at sea through informal chats in the ship's mess or other common spaces, enjoyed being surrounded by the ocean, and reflected on the experience on the CAPSTAN blog. Now a Ph.D. student, Elise has returned to sea on RV *Investigator* as the Principal Investigator for multiple voyages with a micro-plastic focused project and she was slated to be a 2020 CAPSTAN trainer until the COVID-19 pandemic put plans on hold.

Live Crosses

Opportunities for our target audiences to get on board RV *Investigator* are limited. With advanced communication capabilities, the MNF supports activities that allow real-time engagement between RV *Investigator* and audiences around the world. Live crosses enable classrooms, lecture theaters, museums and social media users to experience a virtual tour or live Q&A session with RV *Investigator* while at sea anywhere in Australia's vast marine estate. While applicable to all three audience segments, live crosses are particularly targeted at Purpose Seekers, with 3860 students from every Australian state and territory having participated in a one-on-one live cross since 2016 (**Table 1B**).

Nurturers

Nurturers are aged 25–34 years and are typified by teachers and young parents. This audience segment is typified by concerns for a future

where their children and students can thrive and, as a result, they have more complex information needs than Purpose Seekers (**Figure 1**).

Commonwealth Scientific and Industrial Research Organization Educator on Board

The CSIRO Educator on Board program is a professional learning opportunity for Australian STEM school teachers to participate in voyages on RV *Investigator*. On board, teachers assist scientists and technicians with research, enhance their STEM content knowledge, run outreach activities and develop teaching resources aligned with the Australian curriculum to be trialled in their own classroom and then shared with other teachers nation-wide. Educator on Board aims to support teacher professional development and provide students with a window on the real word application of STEM. Since launching in late 2017, 17 teachers have participated in eight voyages throughout the Australian marine estate (**Figure 2**), totalling 273 education days at sea (**Table 1A**). Quantitative feedback shows that the program increased participants' motivation (9.1 ± 0.9 SD, N = 17) and enthusiasm (8.7 ± 1.3 SD, N = 17) to teach STEM subjects and fostered connections with researchers that have endured post-voyage (9.3 ± 1.1 SD, N = 17). The program also increased teachers' understanding of marine careers (9.3 ± 0.9 SD, N = 17) and encouraged them to inspire their students to explore careers in the marine sector (9.3 ± 0.8 SD, N = 17).

CASE STUDY–EDUCATOR ON BOARD EMILY FEWSTER

Secondary distance education teacher Emily Fewster joined a 15 days voyage on RV *Investigator* as part of the Educator on Board program in December 2018/January 2019. During the voyage into the Tasman Sea (**Figure 2**). Emily worked alongside researchers to collect volcanic rocks from seamounts to help piece together the story of the breakup of Australia and Antarctica approximately thirty four million years ago. Emily worked as part of one of the science shifts, being tasked with sectioning rocks for analysis on a specialized diamond rock saw. As a result of her on-board learning Emily developed a four-part lesson with assessment about plate tectonics in the Australian-Antarctic context aligned with the curriculum (Fewster, 2019). Students learn about mantle plumes and their role in plate tectonics, the careers and technology used in geoscience, how to identify a range of rocks using a dichotomous key and how to identify plate movement based on the age of extinct volcanoes. The lessons feature contemporary research conducted on her voyage.

Floating Classroom

Floating Classroom provides an opportunity for Australian educators to use RV *Investigator's* laboratories and workspaces to deliver education and training activities while the ship is in port. The ship is available for Floating Classroom during port periods when operational requirements permit and is open to secondary and tertiary students. The program aims to increase understanding of how STEM is applied in the real world, seeking to inspire future generations of marine experts. To date, 271 students have participated in Floating Classrooms in Australian ports (**Table 1B**; **Figure 2**).

Lifelong Learners

The demographic of 35–55+ year olds encompassing Generation X and Baby Boomers are the Lifelong Learners. Lifelong Learners are typified by professionals and academics who are continually exploring and discovering new information through science. On average, they have complex information needs (**Figure 1**).

Ship Open Days

With at-sea operations taking RV *Investigator* to ports around Australia and overseas, the MNF seeks to use the vessel as a hub for community engagement events and capitalize on the invaluable tool the vessel offers to capture interest. The MNF makes the vessel accessible for tours and public events, with ship open days a major activity. Open days typically have tours for schools in the morning, followed by the public in the afternoon. During planning, priority is given to ports that the vessel has not visited before, therefore presenting opportunities to engage with new audiences.

Media and Social

The MNF, and CSIRO more broadly, adopt a strategic approach to media activities—both mainstream and social media—in recognition of the crucial role media plays in shaping public awareness and attitudes towards science. To maximize impact, we engage with target audiences through an objective-led framework that seeks to ensure communications are relevant (demonstrate our impact, focus on issues that matter), accessible (make content widely available, encourage content sharing) and appealing (authentic, credible and dynamic content). Audience analysis and segmentation is used to better understand target audience needs as well as identify likely business impact of effective messaging. This enables us to deliver purposeful content to identified and prioritized audience segments, which, in general, also has suitability for a wider audience. For each target audience the most effective channels to reach each is identified—whether that be social channels, mainstream media or a mixed model—as is the appropriate tone of voice and information complexity of content. Delivery of media activities is underpinned by the MNF's highly collaborative approach to all communications, as well as a strong emphasis on producing portable and engaging resources that encourage sharing. To support mainstream media engagement, the MNF offers media exposure and direct access to our research and researchers through both virtual and real experiences, including offering ship tours and opportunities to join research voyages. Through these activities, the MNF supports the wider objective of contributing towards national scientific literacy in order to help mobilize and develop the best talent for the benefit of Australia.

DISCUSSION

In Australia, participation in STEM subjects in schools is declining, with enrolments at their lowest level in twenty years (Kennedy et al., 2014). Overall performance in STEM subjects is

also falling (PISA, 2018). This must improve if the country is to position itself to supply the skills required for future research and industries and is especially important for the marine sector, where a shortage of STEM skills is a major barrier to the sustainable development of Australia's blue economy (National Marine Science Committee, 2015). Key to addressing these deficits are programs that target school aged children, teachers, and students transferring into tertiary education, fostering the translation of students into STEM related occupations in academia, research and industry (Department of Industry, Science, Energy and Resources, 2017). Building marine science literacy in the general community also has an important role to play, as does building awareness of the unique blue-water research capability the MNF provides the Australian research community and their international colleagues to support oceanographic, geological, biological and atmospheric research.

Publicly funded research organisations have a responsibility to deliver emerging, innovative and creative marine science communication and education. Australia's national science research agency, the CSIRO, through the management of landmark research infrastructure like the MNF provides a nexus where the capability gaps and mismatches between the skills in demand by industry, and those taught in schools, the vocational education and training system and universities can be ameliorated. The impact of marine research training delivered in this way is only beginning to be realized, with 86% of surveyed students having participated in an RV *Investigator* voyage reporting that it would be impossible to gain the same quality of research experience and training elsewhere in Australia (Leonchuck et al., 2020). Students also report that they develop personal qualities including perseverance, adaptability and flexibility in the workplace from this training (Leonchuck et al., 2020). The development of these personal attributes is one of the key characteristics that private-sector employers seek in marine science sector students (see MacKeracher and Marsh, 2019) and demonstrates multi-dimensional impact from the MNF outreach and training experience.

A positive influence on the target audience is just one component of an effective outreach program. In an environment of limited funding and resources, it is important that, where practicable, our program also benefits from participants through a two-way exchange of knowledge, rather than a one-way delivery of information and services. The MNF Outreach Program has demonstrated the benefit of knowledge sharing with students and teachers, particularly in the Educator on Board and ITSS programs, to the collaborative marine science effort on voyages. This is especially important for nurturing the incorporation of traditional knowledge systems and Indigenous science into western marine science.

With an increasing recognition of the importance of the role of science communication in informing science literacy and policy, publicly funded national research facilities such as the MNF have an essential role to play by moving away from their traditional research-only roles to also provide for education and communication. Support for this expansion among the research community and facility users is crucial. To foster this support, the MNF now requires all applicants for sea time to address how components of the MNF Outreach Program could be incorporated into their research voyage, partnering with researchers to ensure that successful and meaningful outreach is an imbedded component of their use of the facility. The MNF Outreach Program demonstrates that publicly funded research facilities can and should play a key role in delivering training, education and communication objectives that build capacity and ultimately lead to improved societal value of environments such as the world's oceans. However, it is acknowledged that expansion of the scope of such national facilities does not come without difficulties.

An outreach program centered around a publicly owned, multi-disciplinary research vessel brings with it both opportunities and challenges. Recent welcomed increases to funding has seen RV *Investigator* operating at full capacity; up to 300 days per year at sea. While this presents increased opportunities for at-sea communication and education activities, port periods are necessarily compressed, reducing the ability to host higher volume ship open days and Floating Classrooms. The disruption to sea-going research and new protocols due to the COVID-19 pandemic have further accelerated the demand and uptake of remote, virtual engagement options. Early indications are that these activities have allowed us to reach newer and larger audience segments, suggesting an appetite for the expansion of novel virtual outreach options as a greater part of the MNF Outreach Program in future.

Across the globe marine issues are varied and complex, but the science recognizing the importance of a healthy ocean to life on Earth is well established. Improved societal value of the ocean leading to sustainable decision making can only be achieved when underpinned by effective education and communication. Just as marine issues are complex, marine communication and education needs and approaches must be equally multifaceted. At a regional level differences in marine environments, geography, information needs and socioeconomic circumstances result in multiple combinations of marine subjects and issues across a continuum of relevance to audiences. Designing and implementing an outreach program in this setting is difficult. Just as in other countries, marine issues in Australia are as varied as the environments encompassed by an area spanning the tropics to the pole, with a society spread between those living on the coast to those in the desert 2000 km from the ocean. The MNF Outreach Program demonstrates that these issues can be surmounted, at least in part, by having a spectrum of programs and activities of varying resource intensity which are matched to clear target audience segments.

DATA AVAILABILITY STATEMENT

The data analyzed in this study is subject to the following licenses/restrictions: Data included in the article are program evaluation data, collected for the sole purpose of program development and improvement. Such data relate to the operation of programs and can only be presented in summary format as presented in the article. Requests to access these datasets should be directed to Ben.Arthur@csiro.au.

ETHICS STATEMENT

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

BR, BA, MM, HM, BM and AA conceived the ideas and developed the program. BA, DR, BR, AA and MM wrote the paper.

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