frontiers | Frontiers in Marine Science

ORIGINAL RESEARCH
published: 30 June 2022
doi: 10.3389/fmars.2022.883524

Towards a 2025 National Ocean Literacy Strategy: Current Status and Future Needs in Primary Education

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Specialty section:
This article was submitted to Marine Conservation and Sustainability, a section of the journal Frontiers in Marine Science

Received: 25 February 2022
Accepted: 31 May 2022
Published: 30 June 2022

Citation:
Freitas C, Bellgrove A, Venzo P and Francis P (2022) Towards a 2025 National Ocean Literacy Strategy: Current Status and Future Needs in Primary Education. Front. Mar. Sci. 9:883524. doi: 10.3389/fmars.2022.883524

Globally, ocean health has become critically compromised due to compounding negative human impacts. Marine science education can play a key role in raising collective understanding of the vulnerability of marine environments and the importance of their protection, and this may best begin with integration of ocean literacy in schools. Previous research shows that K-12 students worldwide have a limited understanding of the ocean. This lack of familiarity with the ocean has been linked to the absence of topics related to marine science in most national school curricula. Teachers are the ultimate arbiters deciding whether and how to include these topics in their classes. However, the extent to which marine science may be currently being taught in formal education is still unknown. We used the Australian public school system as a case study to investigate the marine science teaching practices of primary school teachers (Foundation – Grade 6), through an online survey. Our results indicate that while teachers value the importance of ocean education from a young age, most of them rarely or only occasionally cover marine science topics in their lessons. Teachers cited increased levels of marine science knowledge and a greater availability of ocean-related educational resources linked to the school curriculum as key areas for improvement in ocean education practices. This study highlights the importance of formal marine science education in primary education, along with the need for professional development opportunities for teachers.

Keywords: ocean literacy, marine science education, school students, formal education, Australia, teachers, survey

INTRODUCTION

Humans are utterly dependent on the ocean. Covering 71% of the Earth' surface, the ocean holds 97% of the total water on our planet, supports life and diverse ecosystems, and regulates our climate and weather (Fauville et al., 2019). Additionally, marine systems provide countless benefits such as food, medicines, raw materials and energy; and play a cultural role supporting recreational activities that improve our wellbeing (Visbeck, 2018; Otero et al., 2019; Molony et al., 2022). However, ocean health is severely threatened due to a long legacy of anthropogenic activities, leading to a disruption in the normal functioning of the marine environment (Korpinen and Andersen, 2016; Lotze et al., 2018).

Understanding the functioning of the ocean is critical to changing the course of this ecological crisis (Ashley et al., 2019). In this regard, marine science education and outreach play an important role in

promoting ocean knowledge and awareness with respect to its importance for life on Earth, its vulnerability and what we can do to protect it (Dupont and Fauville, 2017; Ryabinin et al., 2019). The Ocean Literacy movement began in 2004, when scientists, educators and policy makers in the USA came together to discuss people's lack of knowledge and awareness about the ocean and marine issues, the deficiency of these topics in K-12 school programs and the need to tackle these challenges (Costa and Caldeira, 2018). Ocean literacy was then defined as "understanding the ocean's influence on you and your influence on the ocean" (Cava et al., 2005). More specifically, an ocean literate person understands the essential concepts about the functioning of marine systems, is capable of meaningfully communicating about the ocean and is able to make conscious choices regarding the marine environment and its resources (Cava et al., 2005).

The promotion of ocean literacy related topics in schools is the starting point to develop a more ocean literate society (Boaventura et al., 2021; McCauley et al., 2021). However, recent studies have shown that K-12 students' level of ocean literacy is often moderate to low (Brody, 1996; Ballantyne, 2004; Guest et al., 2015; Uyarra and Borja, 2016; Leitão et al., 2018; Mogias et al., 2019; Leitão et al., 2022). According to Strang et al. (2007), the science being taught in schools is generally terrestrially-biased, but to be fully science literate, one must be ocean literate and understand unique aspects of the functioning of the ocean (Fauville, 2019). Children are the future custodians of the ocean and schools are the place where they will be exposed to the knowledge and the skills needed to make better decisions to support a healthy, resilient, and sustainable ocean. Nonetheless, this is a challenging job in a world where the ocean is not yet a common topic in the school curriculum across many countries (Mogias et al., 2015; Gough, 2017; Visbeck, 2018; Joyce et al., 2019; Pazoto et al., 2022). Recognising this, the Intergovernmental Oceanographic Commission (IOC) UNESCO has recently published a toolkit that aims to provide orientation and guidelines on how to include ocean literacy in formal education (Santoro et al., 2022). The toolkit highlights the exemplary and promising practices of countries already implementing ocean education in schools, such as Brazil, Canada, Costa Rica, Kenya, Portugal, and Sweden (Santoro et al., 2022).

There is an expectation *via* the United Nations Decade of Ocean Science for Sustainable Development 2021–30 (Ocean Decade) that "By 2025, Ocean Literacy is integrated into the curriculum and education policies of formal education systems around the world, with 70% of countries possessing an approved National Ocean Literacy Strategy" (UNESCO, 2020). As a nation surrounded by sea and a globally recognized hotspot of marine biodiversity, Australia is well placed to lead by example, particularly in relation to marine education. However, despite being an island continent with the third largest marine jurisdiction that includes ecologically and economically significant marine habitats such as seagrass meadows, mangroves, coral reefs, and kelp forests (Arthur et al., 2021), Australia is lagging behind in the ocean literacy movement. Marine science topics are not yet neatly embedded or supported into school curriculum learning areas (Gough, 2017) and specifically, the word "ocean" only appears in the Australian Curriculum in Year 2 and Year 4 Humanities and Social Sciences strands, and in Year 7 and 10 for Earth and Space Sciences (Australian Curriculum Assessment and Reporting Authority, 2016).

For the healthy functioning of marine systems, it is critical to raise awareness of the ocean and this task should start in early education, by providing children with the opportunity to understand and appreciate the connection with their local marine environment (Mogias et al., 2019; Kelly et al., 2021). In southern Australia, this could not be more important, given 67% of the Australian population live within 50km of the southern coastline and depend upon the ecological benefits provided by the unique marine ecosystem of the Great Southern Reef (Bennett et al., 2016). This interconnected, shallow, temperate rocky reef stretches across 8000km of the southern coastline of Australia, is mostly distinguished by its extensive macroalgal forests and has an integral role in the nation's economy and culture (Bennett et al., 2016; Thurstan et al., 2018; Layton et al., 2020). However, it is still relatively unknown (especially in comparison to the northern Great Barrier Reef), and like many global coastal marine environments, it too is threatened by climate change and rapid and unsustainable coastal development (Bennett et al., 2016).

In this respect, teachers are a key target to guarantee the successful inclusion of ocean concepts in schools (Mogias et al., 2015; Lin et al., 2020) and raise awareness about marine environments such as the Great Southern Reef (GSR). Nevertheless, the poor environmental knowledge and awareness, a crowded curriculum and the limited availability of educational resources have been indicated by teachers as reasons not to include ocean education in their teaching practices (Eidietis and Jewkes, 2011; Boubonari et al., 2013; Fauville et al., 2018; Joyce et al., 2019). It is reasonable to expect that teachers are not including marine science concepts regularly in their teaching practices based on these identified barriers, but this hypothesis is largely untested.

We used Australian public schools as a case study to investigate the current marine science teaching practices targeted at the primary school levels (Foundation to Grade 6). We addressed the following questions: (a) Are primary school teachers incorporating marine science in their classes? If so, how often and in which of the distinct Australian Curriculum Areas? (b) Which teaching methods are being adopted in marine science education and how effective are these in engaging students, according to teachers' perceptions? and (c) What factors would motivate teachers to include or improve marine science teaching in their classroom? These research questions were addressed *via* a survey instrument for primary school teachers in government schools across five Australian states within the GSR area: Western Australia, South Australia, Victoria, Tasmania, and New South Wales.

MATERIALS AND METHODS

Survey Development

The survey was designed to take approximately 10 minutes to complete. It consisted of 13 questions, 12 multiple-choice

(including questions with 5-point Likert-scale items) and 1 open-ended question (**Supplementary Material**). Two of the multiple-choice questions were not included in the data analysis of this study as these were aimed at collecting information regarding a broader project outside the scope of this study. The multiple-choice design was chosen because it is less time consuming, allows participants to respond promptly, and facilitates uniform and robust statistical analysis. Some of the questions were adapted from previously published survey instruments exploring teachers' perceptions and practices in environmental education (Ko and Lee, 2003; Eidietis and Jewkes, 2011), while others were specifically formulated according to the research questions and purpose of this study. Most of the questions also included an open-response hypothesis defined by "Other. Please specify". The purpose of this option was to avoid limiting participants in the number of choices provided, allowing them to contribute with other possibilities not previously contemplated by the research team, thus increasing the validity of the survey instrument (Sue and Ritter, 2007). The first 5 questions of the survey instrument were designed to be answered by all participants. Questions 1 to 4 related to the geographic location of each participant's school, teaching grade(s), professional role, and previous training in marine science in the last 5 years, respectively. This limited range of time was chosen to increase the chances of participants providing accurate information (Sue and Ritter, 2007), as it may be challenging to recall training events past this period. The fifth question branched according to each teacher's responses regarding how often they teach marine science in their classes. Participants that do not teach marine science were asked about what would motivate them to teach this topic. On the other hand, for participants that already teach marine science, questions regarding (1) where in the distinct Australian Curriculum Areas they incorporate this, (2) the teaching method(s) used and the teacher's perceptions on the effectiveness regarding students' engagement and (3) what would motivate them to improve their practices towards marine science education were displayed. A final open-ended section was included to allow participants to provide additional comments with regards to the topic being investigated.

As the Australian curriculum learning areas slightly differ across the 5 states of this study, and for the purpose of making results transversal to all the Australian states considered, we have combined different learning areas into one main strand following the survey results. The Humanities strand includes the Humanities and Social Sciences, History and Geography. The Arts strand includes Music, Dance, Drama, Media Arts, Visual Arts and Creative Arts.

All co-authors (with expertise in the fields of marine science, marine education, and children's literature) and 3 primary school teachers (that did not participate in the study), provided independent feedback on the content and wording of the survey questions. The research team discussed the interpretations and achieved a consensus regarding the survey instrument. Minor changes in wording were made to avoid ambiguities and improve readability.

Participant's Recruitment and Survey Administration

Participants were primary school teachers from government primary schools across the five Australian states that border the GSR: Western Australia, South Australia, Victoria, Tasmania, and New South Wales. Only government schools were considered in this research project as they represent the highest proportion of primary schools across the five states considered, and are required to follow specific curriculum guidelines defined by the ACARA (Australian Curriculum Assessment and Reporting Authority, 2016).

A technique called 'saturation sampling', when all the members of a particular population are invited to participate in the research (Sue and Ritter, 2007), was used. A list of 4199 government primary schools in the five states was generated by using the Australian Schools List (Western Australia: 641; South Australia: 440; Victoria: 1294; Tasmania: 150; New South Wales: 1674). Email contacts for these schools were obtained through an internet search (e.g. institution website). It was not possible to calculate the response rate as initial contact (according to government regulations) was established with the school Principal *via* email, and they were requested to forward the invitation to the primary school teachers in their school if they agreed that their staff could participate in the research. All data were collected in a non-identifiable format.

Data were collected through the online survey software Qualtrics (Qualtrics, Provo, UT, 2021). A soft launch was conducted at the time of the first round of data collection (May 2021). The survey was firstly sent to 100 primary schools (50 schools in Tasmania and 50 schools in Western Australia). This method was used to verify and/or detect any errors that could have arisen with respect to emails being sent to schools and/or the participants' responses being appropriately recorded, before sending the online survey to the other 4099 schools. No significant errors were detected, and the data collected from the soft launch were included in the final dataset. Two weeks after the successful soft launch, the survey was sent to the remaining schools. Reminder emails were sent one and two months after the first email that was sent to each school. The survey closed on 31st July 2021.

Data Analysis

Data were entered into a database in Microsoft Excel and analysed using IBM SPSS Statistics (Version 27; IBM Corp, 2021). Descriptive statistics including frequency and percentage were used to analyse quantitative data and make comparisons between survey questions.

To test the null hypothesis that the frequency of marine science teaching was independent from previous training in marine science, a Pearson's Chi-square test was used. To satisfy the assumption that no more than 20% of cells had expected counts less than 5 (Quinn and Keough, 2002), the five frequency categories were collapsed into 2 categories: "Sometimes" (including *Frequently* and *Occasionally*) and "Seldom" (including *Rarely* and *Never*), resulting in a 2×2 table for analysis (**Supplementary Table S1**). All quantitative statistical analysis was tested at $\alpha = 0.05$.

Qualitative data from open-response questions was comprehensively analysed and coded into a list of different categories by using QSR International's NVivo 12 software (QSR International Pty Ltd., 2020), as it allowed capture of specific words and information for each participant' answers and development of corresponding codes. After examining the preliminary categories, a list of 4 main themes (*current teaching*, *ocean stewardship*, *challenges* and *needs*) related to marine science education and 14 sub-themes were generated. These codes were then independently analysed by another marine science educator in the research team. A consensus between the two coders was reached on the final development of categories.

RESULTS

Sample Composition

A total of 124 participants completed and returned surveys from across the five Australian states bordering the GSR (**Figure 1**; NSW: 27, VIC: 58, TAS: 4, SA: 10, WA: 25). Amongst the participants, there was reasonable balance across grades taught from F-2 (40.1%), 3-4 (29.3%) and 5-6 (30.6%; **Table 1**; N=467 as some teachers taught multiple grades). Classroom teachers represented 50% of respondents (N = 62) while 33.9% were specialist teachers. From among the specialist teachers, 79.1% were science/STEM specialists. Teachers that did not identify as classroom or specialist teachers represented the remaining 16.1% of the respondents (**Table 1**).

Classroom Teacher's Experience in, and Frequency of, Teaching Marine Science Education

From the 124 teachers surveyed, 91% (N=113) did not have training in marine science education during the last 5 years. Contrary to our expectations, we found that there was no significant influence of prior training in marine science on the frequency with which teachers incorporate marine science concepts in their classrooms (χ^2 = 2.99, P = 0.098); however, our sample size of teachers with prior training was small (9%) compared to the number of teachers without prior training (91%; **Table 2**). Of that small sample with prior training in marine science, 100% of the teachers implemented marine science teaching a few times a year (i.e. *Rarely*) or more (*Occasionally* or *Frequently*), compared to 88.5% of teachers without prior training (**Table 2**).

FIGURE 1 | Number of returned surveys per each of the 5 states (WA, Western Australia; SA, South Australia; VIC, Victoria; TAS, Tasmania; NSW, New South Wales) bordering the Great Southern Reef (highlighted by the red line).

Curriculum Areas Used to Teach Marine Science

Teachers were asked which curriculum area(s) in the Australian Curriculum they have used for educating about the ocean. The 124 participants were often teaching across mutliple areas, with all of the 9 curriculum learning areas selected at least once, for a total of 244 cases (**Figure 2**). The most commonly chosen response from participants was Science, followed by The Humanitites, English, and The Arts. All the remaining learning areas were selected by less than 20 teachers, with Health and Physical Education being the least mentioned (**Figure 2**).

Marine Science Teaching Methods and Effectiveness

When asked about the methods used to teach marine science topics in class, almost all the participants (87.4%) selected at least two different methods, for a total of 367 cases (**Figure 3**). The most commonly used approaches included *teacher-led learning, use of children's literature* and *classroom inquiry-learning activities*, and these three approaches were also considered very effective most commonly by teachers (**Figure 3**). The teaching method that was considered to be extremely effective by most respondents was the use of *excursions*, but only 43 (34.7%) of teachers employed this method. The category least employed by teachers was *marine science group projects*, but proportionally, was considered most effective by its users (more than 90% of teachers using this method considered it is very or extremely effective in raising children's engagement in marine science topics; **Figure 3**).

Requirements to Improve/Include Marine Science Education in the Classroom

From the 124 participants, 9 reported to be satisfied with their current level of marine science education, and only 1 claimed to see no reason to educate about the marine environment. The other 114 participants were asked about what would encourage them to include/improve their marine science education practices. From the teachers already incorporating marine science in their classes, an increased level of marine science knowledge and the provision of additional supports (i.e. educational resources and assistance from experts) were identified as the most important requirements for improving these practices (49.9%), whereas regulation (i.e. the compulsory inclusion of ocean topics in the curriculum) was a lower motivator (7.6%), for a total of 393 cases (**Table 3**).

TABLE 1 | Survey demographics (N=124 respondents).

		Frequency	*%*
Grades	Foundation – Year 2 (Age 5 – 8)	187	40.1
	Year 3 – Year 4 (Age 8 – 10)	137	29.3
	Year 5 – Year 6 (Age 10 – 12)	143	30.6
	Total	*467*	*100*
		Number	*%*
Professional role	Classroom teacher	62	50
	Specialist teacher	42	33.9
	Science/STEM	34	79.1
	Visual Arts	2	4.7
	Digital technologies	2	4.7
	Sustainability	1	2.3
	Physical education	1	2.3
	Geography	1	2.3
	Library	1	2.3
	Health	1	2.3
	Other	20	16.1
	Teaching principal	12	66.7
	Learning support teacher	3	16.7
	Release teacher	2	11
	Environmental teacher	1	5.6

TABLE 2 | Number (percentage) of participants who taught marine science in their classes *very frequently* (e.g., all, or almost all lessons), *frequently* (e.g., once, or twice a week), *occasionally* (once or twice a month), *rarely* (a few times a year) or *never*, and whether they had any marine science training in the previous 5 years (Yes/No).

Marine Science Training (Past 5 years)	**Marine Science Teaching**					
	Very Frequently	**Frequently**	**Occasionally**	**Rarely**	**Never**	**Total**
No	0 (0%)	4 (3.5%)	29 (25.7%)	67 (59.3%)	13 (11.5%)	113
Yes	0 (0%)	4 (36.4%)	2 (18.2%)	5 (45.4%)	0 (0%)	11
Total	0	8	31	72	13	124

With respect to the teachers that do not currently educate about marine science, the majority (19.5%) indicated that more support to conduct excursions to the natural environment would assist them to include ocean education in their teaching practices. Apart from "an increased knowledge about marine science teaching methods", the least mentioned requirement (9.8%), almost all the other requirements listed showed a similar frequency of mention by participants (between 12 to 14.5%, approximately), indicating that any support and/or regulation will assist them to include ocean education in the classroom (**Table 3**).

Qualitative Analysis of Teacher's Perspectives on Marine Science Education

A total of 36/124 teachers opted to contribute their perspectives of marine science education through the open-ended question at the end of the survey. The answers were analysed and coded into 4 main themesand 14 sub-themes (**Table 4**). Teachers collectively reflected on their current marine science teaching practices and the most common sub-themes to arise here showed that existing educational programs (N=7) and previous knowledge of marine science (N=5) were considered factors that facilitated marine science being incorporated in their classes. Geographic location was considered to be an important influence on science teaching for some respondents: three teachers living beside the ocean believe that one cannot teach science without including ocean topics, whilst four of the teachers living far from the coast reported that their location was a reason to focus more on terrestrial environments rather than marine environments in their science teaching. The second main theme to emerge was the importance of ocean stewardship. Teachers revealed that positive attitudes and behaviours towards a sustainable management of the marine environment (N=10) as well as the importance of how the teachers' and students' connection with the ocean determines best teaching practices and learning outcomes.

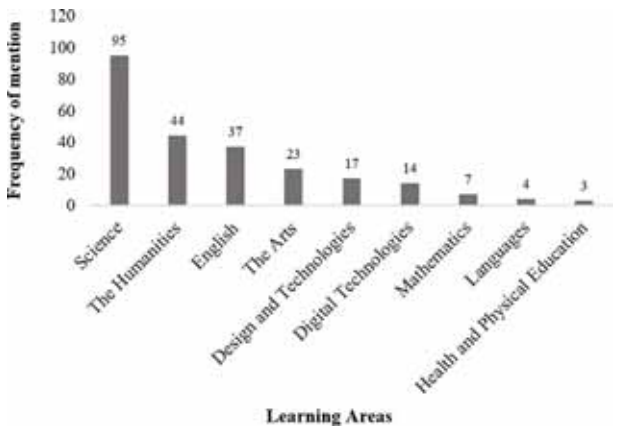

FIGURE 2 | Frequency in which the Australian Curriculum learning areas were used to teach marine science by respondents.

Teachers also shared the challenges faced regarding marine science education. A crowded curriculum was perceived as the most common cause constraining teachers from this practice (N=6) but also challenges relating to geographic location, lack of funding/support and marine science not formally embedded in the Australian Curriculum were also challenges noted. Teachers expressed three actions that were needed to overcome these challenges: 1) a higher availability of educational resources that can be used in the classroom (especially when an excursion to the field is not possible; N=6), 2) more training opportunities in marine science education (N=5), and 3) support from experts in the field (N=4).

DISCUSSION

The inclusion of ocean literacy in school curricula is vital to develop a future in which sustainable ways of living and ocean governance are firmly imbedded. Although this has been recognised in the Ocean Decade goals, there is little evidence that this is a priority in most formal educational systems across the world (Pazoto et al., 2022). Our results demonstrate that ocean literacy is generally lacking in primary schools across the five Australian states bordering the GSR. Even though teachers value the importance of marine science education at a young age, most of them rarely or only occasionally include these topics in their classes. We predicted that teachers with no ocean education training would incorporate marine science less frequently in their classroom compared to teachers who had received training in the last 5 years. Our results showed that this relationship was not significant due to unequal samples sizes. However, teachers who had received training, indicated that their knowledge is a key element motivating them to include ocean education in their lessons. The independent relationship between previous training and ocean education frequency found in this study may indicate that although teachers might have some level of knowledge about ocean concepts, integrating them in their lesson plans are not frequent which may be linked to a heavily prescribed curriculum.

The most common obstacle mentioned by teacher's comments in this study regarding embedding ocean education

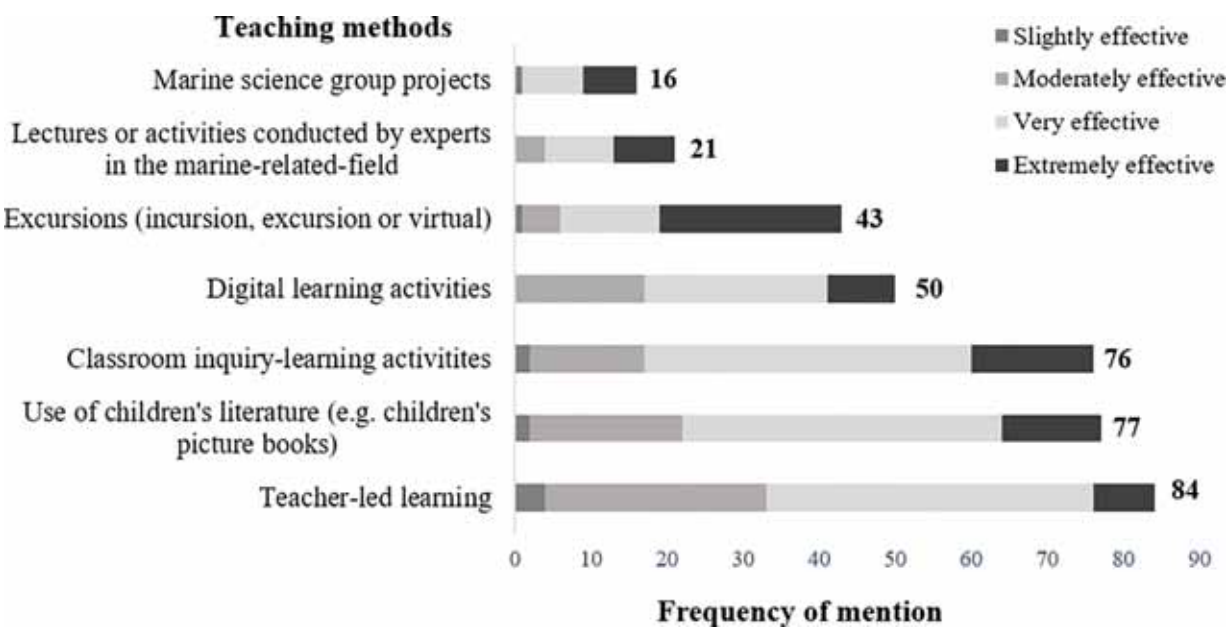

FIGURE 3 | Frequency of teaching methods used by teachers to educate about the ocean (scale) and the effectiveness of those methods according to teacher's opinion (shading).

TABLE 3 | (1) Frequency and percentage of each of the requirements selected by teachers that would lead those already incorporating marine science in their classes them to improve (column A) or those yet to incorporate marine science in their classes to include (column B) marine science topics in their lesson plans.

(1) Requirements	**A**		**B**	
	Frequency	***%***	***Frequency***	***%***
Increased knowledge about marine science	**73**	**18.6**	6	14.6
Higher availability of educational resources (e.g., textbooks, marine science kits)	62	15.8	6	14.6
Support of experts in the field (e.g., marine scientists)	61	15.5	6	14.6
Increased knowledge about marine science teaching methods	60	15.3	4	9.8
More support to conduct excursions in the natural environment	54	13.7	**8**	**19.5**
Specialised training about how and where to include marine science in the distinct curriculum areas	53	13.5	6	14.6
The compulsory inclusion of marine science topics into the national curriculum	30	7.6	5	12.2
Total	393	100	41	100
(2) Statements				
I am already comfortable with my current marine science teaching practices	9	–	–	–
I do not see a reason to include marine science topics in my class	–	–	1	–

(2) Number of teachers that do not intend to improve (column A) or include (column B) marine science topics in their classes. Bold values correspond to the highest frequency and % in each column.

TABLE 4 | Themes and frequency of mention for each specific sub-theme coded based on teacher's perceptions on marine science education in southern Australia.

Themes	**Sub-themes**	**Frequency of mention**	**Teacher ID**
Current teaching	Use of available educational programs	7	T3, T15, T16, T17, T22, T25, T26
	Marine science background	5	T7, T9, T14, T21, T31
	Proximity to the coast	3	T1, T22, T28
Ocean stewardship	Sustainable future	6	T6, T8, T14, T28, T33, T34
	Teacher's connection with the ocean	2	T23, T34
	Students' connection with the ocean	2	T13, T19
	Research	1	T9
Challenges	Crowded curriculum	6	T8, T11, T12, T14, T27, T29
	Distance from the coast	4	T4, T13, T15, T32
	Not part of the curriculum	4	T5, T15, T26, T29
	Lack of funding/difficulty in organising excursion	3	T24, T27, T33
Needs	Educational resources	6	T19, T21, T24, T27, T28, T32
	Training/Professional development	5	T8, T16, T19, T27, T36
	Support from experts	4	T1, T21, T30, T32

into the program is an already crowded curriculum. We acknowledge this is not an easy problem to solve. Following the guidelines from the newly published toolkit "A New Blue Curriculum", one potential solution is the integration of marine science across the many curricula learning areas (Santoro et al., 2022). This study showed that when teachers educate about the ocean, they are already embracing this cross-curricula approach. This synergy is especially important since ocean issues are complex and demand transdisciplinary approaches (Barracosa et al., 2019). However, our results did show that whilst marine science has the capacity to be taught broadly across disciplines, science was shown to be the learning area most used by educators to teach ocean topics – an unsurprising result – as this learning area offers numerous opportunities to embed ocean education (Gough, 2017).

Other learning areas commonly used by teachers in this study to educate about the ocean were the Humanities, English and the Arts. Children's literature was the second most mentioned teaching method to teach marine science and 71% of respondents classified the use of children's books to be very or extremely effective in engaging children to learn about the ocean. Children's literature is a literary artform that provides a space for language development and can be used to increase pupils' understanding about science as it offers content knowledge and promotes inquiry and problem-solving scenarios (Wells and Zeece, 2007; Hadzigeorgiou, 2016; Mahzoon-Hagheghi et al., 2018; Aurélio et al., 2021). For instance, Ansberry and Morgan (2010) described a study where students from a third-grade cohort scored higher in science assessments when using picture books compared to students using the textbook only. Therefore, using quality children's literature may enhance a child's connection with the ocean and help develop positive attitudes towards science. Previous work reviewed and aligned 100 ocean-themed picture books with the Australian science curriculum for K-6 levels and found multiple

examples of picture books that can be used to teach the scientific concepts in the curriculum (Francis et al., 2021). We suggest that the scientific concepts in the Australian Curriculum are applicable to science curricula worldwide and children's literature can be applied interchangeably.

While picture books can be an effective tool for teaching marine science in the classroom, this study found that teacher-led learning (Cotterell, 2021) was the most used approach by participants. Although theoretical knowledge is essential to develop ocean literate students, it is not always easy to immediately relate it to the real world. In this sense, excursions to the field are an alternative and exciting way of promoting connection and understanding of the local marine environment (Dennison and Oliver, 2013; Fiennes et al., 2015). Although most teachers in this study agreed that this is a very effective method in engaging children to learn about the ocean, qualitative data indicated the difficulty in organising excursions, due to lack of funding and safety concerns. Additionally, teachers also indicated that more support to conduct these activities would improve their ocean education practices. A recent study identified 47 informal marine science education providers across the 5 Australian states bordering the GSR in which 35 stated that their most popular educational program involved hands-on experience and learning out in the environment (O'Brien M., 2021; unpublished data). This result suggests that teachers might be aware of these activities, but costs for these programs may remain a barrier.

It is interesting to note that, while most respondents did not receive prior training in the past 5 years, and rarely or only occasionally teach marine science concepts, almost all indicated requirements that would encourage them to improve or include these topics in their classes. The most common requirement was a better level of marine science knowledge. This result is in line with previous research that indicates that the effective inclusion of marine science education in school settings is, to some degree, reliant on educators that have a solid knowledge of the functioning of the marine environment, which in turn determines what and how they teach (Mogias et al., 2015; Markos et al., 2017). Moreover, if teachers have a strong connection with the ocean, there is a good possibility that this inspires their students to seek their own connections, despite the obstacles they may find (Boubonari et al., 2013). However, this connection may potentially be related to teachers' geographic proximity to the coast – which facilitates the inclusion of marine science topics in the curriculum (Santoro et al., 2022). For example, previous studies have shown that students from schools located near the coast presented a higher level of ocean literacy than students from non-coastal schools (Mogias et al., 2019; Lin et al., 2020), however this was not the case for Greek students (Mogias et al., 2019). Results from this study indicated that teachers living away from the coast focus their science teaching to more relatable terrestrial environments. This is not surprising given the difficulty in accessing the ocean, especially considering the lack of support to organise field excursions and the lack of educational resources that can somewhat transport students to experience the marine environment without leaving the classroom (e.g., virtual reality). For schools that are unable to conduct coastal excursions, whether due to location or lack of resources, we recommend that ocean literacy can be integrated into the curriculum through adopting a broader catchment approach and focus on the ocean's connection to local rivers, creeks or waterways.

The teachers surveyed in this study are from the 5 Australian states where the GSR is their closest marine environment (with the exception of schools located north of Kalbarri, Australia's western limit for the GSR), and thus, teaching marine science concepts that relates to their local ocean will encourage ocean connection and stewardship (Lai, 2021). Unfortunately, due to the low level of public awareness of this reef, educational resources about the GSR for primary school education are in limited supply (e.g., Australian published picture books about the ocean, largely focus on tropical environments; Francis et al., 2021). Based on our findings, it could be argued that the lack of ocean education in Australian schools, may be a contributor to the overall low public perception of the GSR.

More than half of the teachers agreed that specialised training about how and where to include ocean topics in the distinct curriculum areas would also enhance their marine science teaching practices. This is consistent with previous studies, emphasising the need for training programs pertaining to environmental education at both the pre-service and in-service teacher levels (Duncan et al., 2017; Gardner et al., 2019; Scott and Sulsberger, 2019). Teachers in this study also pointed out that they would be more inclined to include marine science in their classroom if there was a higher availability of educational resources. A similar result was found by McPherson et al. (2020), where teachers identified the availability of educational resources aligned with the curriculum strands and aims as an important element affecting the inclusion of ocean topics in their lesson plans. Within the GSR region there are many informal marine science education providers, where educational experiences and resources relating to the ocean are available for teachers (O'Brien M., 2021; unpublished data). However, the supply of those that align with the national curriculum may be limited and educators might not know where to find it. For instance, teachers in Australia may be unaware of the annual "Seaweek" ocean education campaign, which provides teaching resources that can be used in schools and are aligned with the Australian Curriculum. The demand for ocean-related educational materials is in alignment with the Ocean Decade's goal in aiming to provide schools with access to ocean literacy educational resources with relevance to the global issues, but also aligned with each local school context (UNESCO, 2020). We recommend a consolidation of resources through a united platform accessible to teachers.

In this study we have identified the most common obstacles faced by primary school teachers regarding the inclusion of ocean education in the curriculum, and the kinds of support and training that may be beneficial to them in assisting and incorporating marine science teaching. Environmental education research specific to the marine environment is in its infancy, which has delayed the development of innovative ocean education solutions (Santoro et al., 2017). Therefore, we can speculate that most countries across the world are facing barriers comparable to those

encountered in Australia with regards to integrating ocean literacy. While local approaches may be required, global collaboration (i.e. "A New Blue Curriculum") is necessary to overcome these challenges.

Our results, however, were subject to some limitations. Although every effort was made to reach large numbers of teachers across government schools in Australia, participation was relatively low. The value of these types of studies can be improved by larger sample sizes, however this is a challenge when the recruitment of teachers is highly dependent on the school Principal's decision to allow research in their school, which can lead to limited participation by classroom teachers. Moreover, this study was conducted during the COVID-19 pandemic which may have led Principals to opt out of research studies, reducing the burden on teachers during this challenging time.

Marine science education at an early age is an effective way to strongly enhance personal connections with the ocean and to motivate people to act towards its protection and conservation (Jaksha, 2019). However, ocean education remains overlooked in Australian primary schools, resulting in a society that is not yet well-prepared to deal with the challenges facing marine environments. Australia needs to reinforce its commitment to valuing the ocean by promoting pedagogies on marine science that empowers schools, considers professional development opportunities for teachers, and creates immersive learning environments in ocean literacy, if we are to achieve the Ocean Decade Agenda by 2025 (UNESCO, 2020). This is especially relevant as the Australian curriculum is currently under review and is expected to be implemented in schools during the next few years (ACARA, 2022). This offers an ideal opportunity to work towards a more ocean-literate generation by considering an integrative, transdisciplinary, and context-rich curriculum approach, placing Australia at the forefront of the ocean literacy movement, and thereby contributing towards a sustainable future for our ocean.

DATA AVAILABILITY STATEMENT

According to the conditions of approval to conduct this research, in the case that access to the data is requested, the individual(s) seeking access require permission granted from the data custodians in addition to Human Ethics approval from the relevant institution(s). Requests to access the datasets should be directed to CF, cabreudefreitas@deakin.edu.au.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Deakin University Human Ethics Advisory Group (Project # SEBE-2020-38-MOD01), Western Australia Department of Education (D21/0076529), New South Wales Department of Education (SERAP 2020323), Department of Education South Australia (2020-0049),

Department of Education Tasmania (2020-33), Department of Education and Training Victoria (021_004404). The ethics committee waived the requirement of written informed consent for participation.

AUTHOR CONTRIBUTIONS

CF and PF designed the study, carried out the research and analyzed the data. AB and PV contributed to the interpretation of data. All authors wrote sections of the manuscript, contributed to manuscript revision, and read and approved the submitted version.

FUNDING

This work was funded by Deakin University, School of Life and Environmental Sciences Higher Degree by Research funds (2022).

ACKNOWLEDGMENTS

This study was assessed and approved by the Deakin University Human Ethics Advisory Group (Project # SEBE-2020-38-MOD01) and by the five state education departments involved. The authors would like to acknowledge the cooperation of the Departments of Education from the 5 Australian states considered in this study and thank the valuable contribution of all the primary school teachers that participated in the survey.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2022.883524/full#supplementary-material

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