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Evaluating the Impact of an Interdisciplinary School-Based Marine Education Curriculum on Ocean Literacy Among High School Students

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Abstract

This study evaluated the effectiveness of a school-based marine education curriculum in enhancing ocean literacy (OL) among high school students. The study designed such a curriculum and investigated its influence on students' OL. A total of 1,284 first-year high school students were recruited and divided into an experimental group (n = 287) and a control group (n = 997). Students in the experimental group participated in a 16-week school-based marine education curriculum, while the control group received marine education integrated into general academic subjects. Both groups completed pre-tests and post-tests measuring OL. The OL survey used in this study was designed based on Taiwan's Curriculum Guidelines of 12-Year Basic Education, comprising 40 questions across five learning topics. Previous validation established strong reliability and validity (content, convergent, and construct validity) for the instrument, with item response theory analyses indicating moderate-to-easy difficulty (ranging from -3.157 to 1.564). Results showed no significant difference between the experimental and control groups at pre-test (t = 0.79, p = .429). However, both groups significantly improved their OL scores at post-test, with the experimental group (*Mean* = 29.77) scoring significantly higher than the control group (*Mean* = 27.01; t = 8.02, p < .001, Cohen's d = 0.54). Furthermore, the experimental group significantly outperformed the control group in marine leisure, marine science and technology, and marine resources and sustainability. This study confirms that the school-based marine education curriculum effectively enhanced students' OL, suggesting that schools should emphasize practicality and locality in curriculum design and provide professional development opportunities for teachers to further enhance students' ocean literacy.

Key words: Sustainable Development, School-Based Curriculum, Ocean Literacy, Marine Education, Student Learning Outcomes

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Introduction

A growing amount of attention has been given to the importance of the marine environment, and ocean literacy (OL) has thus become a key part of education worldwide. In 2004, the United States launched an OL campaign for students and the general public. The term OL refers to understanding the influence of humanity and the ocean on each other (Cava et al., 2005). OL is crucial for raising awareness of ocean conservation among students and the general public and shaping their behavior. The concept of OL came to be clearly defined during the early 2000s by a group of ocean scientists, educators, and policymakers. These individuals recognized a notable gap in formal education, namely, the absence of a comprehensive framework for learning about the ocean. They developed a series of conceptual flowcharts and arrived at a consensus regarding a definition for OL, and this definition has become the most widely recognized in academia (Cava et al., 2005). Additionally, the National Marine Educators Association (NMEA) developed seven key principles of OL. The NMEA further connected them to 45 learning concepts in ocean science and used these concepts to produce instructional materials and assessment guidelines (Halversen et al., 2021; National Oceanic and Atmospheric Administration [NOAA], 2013, 2020).

Various countries have widely accepted the principles of OL, and studies have compared the implementation and level of OL between countries (Cavas et al., 2023; Fauville et al., 2019; Fielding et al., 2019; Tsai et al., 2023). A consensus has already been reached regarding how scientific knowledge on the ocean should be pedagogically structured. Thus, studies on OL have focused on marine knowledge and have established a tool for assessing OL among students and the general public that is valid regardless of culture or socioeconomic background (Fauville et al., 2019).

Considerable progress has been made in research regarding students' OL and ocean science knowledge (Boaventura et al., 2021; Cavas et al., 2023; Chang, 2019; Fauville et al., 2019; French et al., 2015; Glithero & Zandvliet, 2021; Guest et al., 2015; Markos et al., 2017; Mogias et al., 2019; Mokos et al., 2020; Paredes-Coral et al., 2021; Steel et al., 2005; Tsai, 2019; Tsai & Chang, 2024; Tsai et al., 2023). For example, Steel et al. (2005) indicated that residents in coastal areas generally possess higher ocean knowledge than those in other types of areas, possibly related to their living environment. Plankis and Marrero (2010) demonstrated that American students, as well as American adults, generally have low OL; students often struggled to articulate their relationship with the ocean and how the ocean affects their lives. Guest et al. (2015) revealed that Canadian students aged 12 to 18 generally had low marine knowledge scores, yet held strong values regarding the marine environment and exhibited considerable interest in ocean-related careers. Marine education programs in the United States emphasize interdisciplinary learning and encourage student participation in field studies and community service (Baker et al., 2018). In Australia, marine education is vital for enhancing students' environmental awareness, and many schools have designed specialized curricula. European countries like Sweden and the United Kingdom have integrated interdisciplinary approaches involving science, sociology, and environmental education, enabling students to understand ocean-related topics from diverse perspectives (Miller et al., 2018).

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OL is particularly crucial in Taiwan, given its status as an island in the Pacific region. Recognizing this, the Taiwanese Ministry of Education published the "Marine Education Policy White Paper" in 2007. This policy outlined development directions and goals for marine education and means of incorporating them into Taiwan's Grade 1–9 Curriculum Guidelines. In 2013, the Ministry proposed a plan explicitly including marine education in Taiwan's basic education curriculum to cultivate OL and environmental awareness. Subsequently, marine education became a key topic in Taiwan's Curriculum Guidelines of 12-Year Basic Education, comprehensively implemented in elementary, junior high, and senior high schools. The establishment of the Taiwan Ocean Affairs Council in 2018 and the passing of the Basic Ocean Law in 2019 further integrated oceanic thinking into education, enhancing students' OL and encouraging marine conservation. Research indicates that Taiwan's marine education policy has significantly improved students' OL (Tsai & Chang, 2024) and aligns with Ocean Science Decade Challenge 10 (Intergovernmental Oceanographic Commission of United Nations Educational, Scientific and Cultural Organization [UNESCO-IOC], 2021a), emphasizing knowledge systems, communication strategies, education, and cultural connections to enhance OL (Glithero et al., 2024).

Studies within Taiwan have also highlighted specific factors influencing OL. Tsai (2019) discovered personal factors as primary influencers of high school students' OL, though school-level factors also played a significant role. Lwo et al. (2013) emphasized that teachers' marine knowledge directly affects students' learning outcomes. Chang (2015) indicated that Taiwanese middle school students generally have insufficient marine science knowledge, achieving an average correct response rate of approximately 50%. Chang et al. (2014) argued that adequate teacher knowledge and effective teaching strategies are essential for successful marine education implementation.

Enhancing OL is closely related to sustainable development, particularly the United Nations' 14th Sustainable Development Goal (SDG14), "Conserve and sustainably use the oceans, seas and marine resources" (United Nations, n. d.). Educational institutions should emphasize the connection between OL and sustainable development when designing curricula to cultivate long-term environmental responsibility. School-based curricula can incorporate local marine environments, active learning strategies, and community involvement to enhance OL. However, few quantitative studies have systematically evaluated the impact of such curricula on student learning outcomes, especially regarding marine education. Research is needed to establish comprehensive marine education curricula and systematically analyze the effectiveness of OL interventions.

In Taiwan, the "substantial content of marine education" in the Curriculum Guidelines of 12-Year Basic Education (Ministry of Education, 2014), which was implemented in 2019, includes the topics of marine leisure, marine society, marine culture, marine science and technology, and marine resources and sustainability (Table 1). The content focuses on marine scientific knowledge and marine resources and sustainability concepts in SDG14. Furthermore, it integrates Taiwan's unique local knowledge and indigenous traditional knowledge regarding marine society and culture.

This study thus designed a school-based

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Table 1. Marine education topics in the Curriculum Guidelines of 12-Year Basic Education

Learning topics (connotations)	Content (senior high school)
Marine leisure	U1. Being familiar with water sports and possessing the knowledge of safety. U2. Planning and participating in various water recreation and tourist activities. U3. Understanding fishing villages and coastal landscapes and the relationship between cultural customs and ecotourism.
Marine society	U4. Analyzing marine industries and technological development and evaluating the relationship between marine industries and economic activities. U5. Understanding and paying attention to ocean-related laws and policies. U6. Analyzing the evolution of the marine history of Taiwan and other countries and evaluating their similarity and difference. U7. Understanding Taiwan's maritime rights and interests and strategic position.
Marine culture	U8. Making good use of various writing styles and skills to create literary works with the ocean as the background. U9. Recognizing the value, style, and cultural context of various marine arts. U10. Comparing the evolution of ocean-related folk beliefs in Taiwan and that in other countries.
Marine science and technology	U11. Understanding the physical and chemical properties of the ocean. U12. Understanding the influence of ocean structure, seabed topography, and ocean currents on the marine environment. U13. Investigating the relationship between marine environmental changes and climate change. U14. Understanding global hydrosphere relationship between, ecosystems and biodiversity. U15. Being familiar with ocean-related applied science, such as seawater desalination, shipping, tidal power generation, and mineral extraction.
Marine resources and sustainability	U16. Examining the management strategies and sustainable development of marine biological resources. U17. Understanding marine resources such as minerals and energy and their economic values. U18. Recognizing waste accumulation in marine life and the environment caused by marine environment pollution as well as proposing coping strategies. U19. Understanding problems of the hometown marine environment and actively participating in ocean preservation activity.

Source: Ministry of Education, 2020.

marine curriculum, implementing instruction to explore its influence on Taiwanese high school students' OL. The research provides empirical support for future educational policies and promotes further development of marine education in Taiwan.

Therefore, the present study was conducted with consideration of the following objectives:

(1) To what extent does the implementation of the school-based marine education curriculum lead to a statistically significant improvement in high school students' OL?

(2) What specific differences in OL are observed between the experimental group, which participated in the marine education curriculum, and the control group, which received traditional instruction?

(3) How does gender influence the OL outcomes of students in both the experimental and control groups?

Methods

Participants

The participants in this study were first-year high school students. They were divided into an experimental group and a control group. Students

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in the experimental group received marine education through a school-based curriculum delivered for 2 hours per week over 16 weeks. Students in the control group are required to take a mandatory Earth Science course during the first semester of their first year in high school, which includes knowledge related to marine education. Furthermore, teachers can integrate marine education into instruction for other subjects.

The experimental group comprised 10 classes from 2 public high schools in northern Taiwan. Both schools are committed to promoting marine education and have agreed to participate in the experiment involving teaching the marine education curriculum. Students in the experimental group completed an OL pre-test during the first week of the school year. They completed the survey again after implementing the 16-week school-based marine education curriculum. In total, 287 students participated in the marine education curriculum and completed the pre-tests and post-tests.

The control group comprised students from 28 classes from 2 high schools each in northern, central, southern, and eastern Taiwan. Students in the control group received instruction in which marine education was integrated into teaching other subjects over 16 weeks. In this group, 997 students completed the curriculum and pre-test and post-test surveys on OL.

Marine education curriculum

This study considered Taiwan's Curriculum Guidelines of 12-Year Basic Education in developing a teaching model for high school marine education to cultivate OL. The curriculum was taught by teachers at the participating schools, most of whom were qualified to serve as seed teachers in marine education. The course was divided into five parts. The first four parts were:

(1) Environmental challenges;
(2) Resources and sustainability;
(3) Cultural identity and preservation;
(4) The ocean and me.

Each part was taught for 2 hours per week over 3 weeks. The course content primarily guided students in becoming aware of ocean-related topics. The fifth part of the curriculum involved creating a marine guardianship action plan. Students were asked to apply what they learned in the first 12 weeks to develop a marine guardianship action plan. This part of the curriculum focused on guiding students in brainstorming and planning proposals and subsequently practically implementing and presenting their action plans. The course content design is presented in Table 2.

Environmental challenges

This part of the curriculum introduces various forms of marine pollution and contemporary examples of key relevant incidents in international waters and Taiwan. This information is included to broaden students' understanding of marine pollution. Students learn about marine-related green energy through data analysis and explore various ocean energy sources (e.g., waves, tides, and currents).

Resources and sustainability

This part of the curriculum was developed based on statistical data from the Taiwan Fisheries Agency. It focuses on changes in the production and value of distant water fisheries, nearshore fisheries, and aquaculture. The focus of this part is to convey the reality and urgency of marine biological resource depletion to foster the ability of stu-

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Table 2. Marine courses and contents

Date (week)	Unit/Topic	Content outline
1	Environmental challenges	Course introduction/state of marine pollution
2		The energy situation in Taiwan
3		Marine energy as a new energy type
4	Resources and sustainability	Resource crises for marine creatures
5		Environmentally friendly seafood consumption (1)
6		Environmentally friendly seafood consumption (2)
7	Cultural identity and preservation	Getting to know life in fishing villages
8		Marine travel planning
9		Taiwan's marine history
10	The ocean and me	Exploring marine careers
11		The beauty of the ocean
12		The ocean in our lives
13	Action proposal for marine protection	Proposal ideas
14		Proposal planning
15		Proposal completion
16		Proposal presentation and reflection

dents to empathize with the survival of marine life. The curriculum guides students to apply ecological principles and select environmentally friendly seafood in their daily consumption practices. In doing so, it encourages them to consider how they, as consumers, can help mitigate overfishing.

Cultural identity and preservation

This part of the curriculum introduces students to the unique fishing villages and fishing culture of the coastal regions of Taiwan. It encourages students to respect, appreciate, and actively engage in the lifestyles of these fishing communities. Additionally, it highlights that the Austronesian peoples originated in Taiwan, enabling students to learn about Taiwan's history and development.

The ocean and me

This part of the curriculum involves guiding students in exploring ocean-related industries based on their interests. When learning this part of the curriculum, students use the internet to research these industries and search for ocean-related jobs on job bank websites. Students learn about such jobs' required skills, responsibilities, and salary ranges.

During the 16-week course, students were organized into small groups, which were their groups for their final marine guardianship action plan. They collaborated in all activities, engaging in course learning and group discussions (Figure 1).

Measurement instruments

The OL survey used in this study was developed by Tsai (2019) and comprises 40 OL-related items. The items were developed based on the content on marine education outlined in the Curriculum Guidelines of 12-Year Basic Education, which encompasses five learning topics: marine leisure, marine society, marine culture, marine science and technology, and marine resources and sustainability. Each of these themes is represented by several

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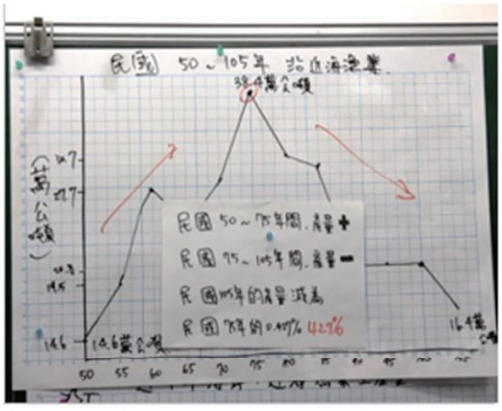
(a)



(b)



(c)



Figure 1. Activities during the 16-week course

Note: The activities include (a) Students create and analyze a chart showing the changes in nearshore fishery production; (b) Students are challenged to select sustainable seafood from commonly found options in supermarkets; (c) Students collaboratively trace the historical context of Taiwan's maritime history.

fundamental concepts that students must learn (Table 1), with 19 of such concepts in total. Table 3 presents the number of survey items related to the five learning topics. Each item is a multiple-choice question with four options. Each correct response is assigned a value of 1, and each incorrect response is 0. The total score of the survey is 40 points. Tsai demonstrated that this survey has good reliability and validity (in terms of content, convergent, and construct validity). According to an item response theory analysis, item difficulty ranged from -3.157 to 1.564, indicating that this survey is moderately easy.

Data analysis

Descriptive statistics were used to describe the sampling distribution. A *t*-test was employed to identify significant differences in OL scores between the pre-test and post-test. All statistical analyses were conducted using the statistical package for JASP (Jeffreys's Amazing Statistics Program; https://jasp-stats.org). For all statistical tests, significance was set at $\alpha = .05$.

Results

Descriptive statistics

This study included 1,284 participants, who were divided into experimental and control groups. The experimental group comprised 287 participants with 140 male students (48.8%) and 147 female students (51.2%). The control group comprised 997 participants with 489 male students (49.0%) and 508 female students (51.0%). The male-to-female ratios in the experimental and control groups were similar to each other and with the male-to-female ratio of the population of Taiwan. Thus, the influence of gender was controlled for on the outcomes in the current study.

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Pre-test and post-test

Before the marine curriculum was implemented, the experimental and control groups completed the OL survey. The results, presented in Table 4, indicated that the total scores for the experimental and control groups were 24.78 and 24.52 (out of 40), respectively, with no significant difference between the groups (p = .401). The two groups also had similar scores across the five learning topics of the marine education-related content, and the scores for each theme did not significantly differ. The range of effect size (Cohen's d) reported, from -0.04 to 0.11, indicates effect sizes ranging from a small negative effect to a small positive effect. This suggests the magnitude of the group differences between the means was relatively modest across the various topical domains assessed. This indicates that the two groups' OL was similar before the intervention.

In addition to comparing the overall differences between the two groups, this study compared the OL between the male and female students within each group. The range of Cohen's d reported in Table 5 spans from -0.14 to 0.25, indicating relatively modest differences in the *Mean* scores between male and female groups across the various learning topic domains. The effect sizes range from small negative to small positive, suggesting the magnitude of the group differences was not substantial. The largest positive effect size was observed for the "Marine culture" learning topic (d = 0.25), while a small negative effect was found for "Marine science and technology" (d = -0.14). The Cohen's d values reported in Table 6 indicate relatively modest differences in performance between male and female students in the experimental group. The largest difference was observed in the "Marine resources and sustainability" domain (d = -0.49), while the smallest difference was found in the "Marine leisure" domain (d =

Table 3. List of learning topics and their alignment with the questions

Learning topics	Number of items	Questions
Marine leisure	8	1 ~ 8
Marine society	10	9 ~ 16, 37 ~ 38
Marine culture	8	17 ~ 24
Marine science and technology	8	25 ~ 32
Marine resources and sustainability	6	33 ~ 36、39 ~ 40

Table 4. Difference testing of pre-test OL scores between the experimental and the control group

Learning topics	Control group (n = 997) *Mean* (*SD*)	Experimental group (n = 289) *Mean* (*SD*)	t	p	Cohen's d
Marine leisure	5.56 (1.30)	5.46 (1.34)	1.13	.257	-0.08
Marine society	6.36 (1.97)	6.22 (1.81)	1.12	.264	-0.07
Marine culture	4.97 (1.39)	4.87 (1.34)	1.10	.274	-0.07
Marine science and technology	3.87 (1.60)	3.81 (1.52)	0.54	.589	-0.04
Marine resources and sustainability	4.02 (1.14)	4.15 (1.21)	-1.69	.091	0.11
Total score	24.78 (5.03)	24.52 (4.47)	0.84	.401	-0.05

Note: ocean literacy (OL).

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Table 5. Difference testing of pre-test OL scores in the control group by gender

Learning topics	Male (n = 489) *Mean* (*SD*)	Female (n = 508) *Mean* (*SD*)	t	p	Cohen's d
Marine leisure	5.49 (1.35)	5.64 (1.24)	1.86	.063	0.12
Marine society	6.21 (2.10)	6.50 (1.82)	2.29	.022	0.15
Marine culture	4.79 (1.52)	5.14 (1.23)	4.03	< .001	0.25
Marine science and technology	3.99 (1.65)	3.76 (1.55)	2.26	.024	-0.14
Marine resources and sustainability	3.89 (1.29)	4.14 (0.96)	3.53	< .001	0.20
Total score	24.36 (5.66)	25.18 (4.31)	2.55	.011	0.16

Table 6. Difference testing of pre-test OL scores in the experimental group by gender

Learning topics	Male (n = 140) *Mean* (*SD*)	Female (n = 147) *Mean* (*SD*)	t	p	Cohen's d
Marine leisure	5.49 (1.43)	5.44 (1.27)	-0.320	.751	-0.04
Marine society	6.11 (1.99)	6.35 (1.62)	1.120	.265	0.13
Marine culture	4.76 (1.52)	5.00 (1.14)	-1.520	.129	0.18
Marine science and technology	4.03 (1.62)	3.61 (1.39)	2.370	.019	-0.27
Marine resources and sustainability	3.88 (1.39)	4.44 (0.92)	-3.990	< .001	-0.49
Total score	24.26 (5.34)	24.83 (3.38)	-1.067	.287	-0.16

-0.04). The results indicate that the male students in both groups significantly outperformed the female students for items related to marine science and technology. However, the female students generally had higher scores for the other learning topics.

The post-test data were analyzed using an independent sample t-test, and the results are presented in Table 7. At the end of the 16 weeks, the control group's average score improved from 24.78 to 27.01, and the experimental group's average score improved from 24.52 to 29.77. Both groups exhibited significant improvement. However, the results indicate that students taught using the school-based marine curriculum scored significantly higher in OL than did those in the control group (t = 8.050, p < .001). In terms of the learning topics, the experimental group significantly outperformed the control group for marine leisure (t = 5.32, p < .001), marine science and technology (t = 9.62, p < .001), and marine resources and sustainability (t = 8.01, p < .001). However, no significant differences were noted between the groups in marine society and marine culture. The Cohen's d values indicate varying degrees of difference between the experimental and control groups across the different learning topics. The largest difference was observed in the "Marine science and technology" (d = 0.63), suggesting the experimental group performed notably better in this area compared to the control group. Sizable differences were also found in the "Marine resources and sustainability" and "Marine leisure" (d = 0.53 and 0.35, respectively). In contrast, the differences were relatively smaller in the "Marine society" and "Marine culture" (d = 0.08 and 0.07, respectively). Overall, the marine education curriculum appears to have had a measurable impact on student learning outcomes in the different topical areas.

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The statistical comparison of pre-test and post-test OL scores for both the control and experimental groups revealed several noteworthy findings (Table 8). For the control group, there was a statistically significant improvement across all learning topics and the overall total score, with all *p*-values less than .001. The Cohen's *d* effect sizes ranged from 0.14 to 1.04, indicating a small effect, suggesting the control group's learning experience led to a modest degree of improvement.

The results for the experimental group were even more compelling. Across all the specific learning topics, from marine leisure to marine resources and sustainability, as well as the overall total score, the experimental group demonstrated statistically significant gains from pre-test to post-test, with all *p*-values less than .001. Moreover, the Cohen's *d* effect sizes for the experimental group were generally larger than those of the control group, indicating the interventions implemented for the experimental group had a substantial impact on their learning outcomes.

These findings demonstrate that both the control and experimental groups experienced mean-

Table 7. Difference testing of post-test OL scores between the experimental and the control group

Learning topics	Control group (n = 997) *Mean* (*SD*)	Experimental group (n = 289) *Mean* (*SD*)	*t*	*p*	Cohen's *d*
Marine leisure	5.89 (1.61)	6.45 (1.50)	5.32	< .001	0.35
Marine society	6.49 (2.13)	6.66 (1.83)	1.26	.208	0.08
Marine culture	5.71 (1.61)	5.83 (1.38)	1.19	.234	0.07
Marine science and technology	4.43 (1.90)	5.63 (1.76)	9.62	< .001	0.63
Marine resources and sustainability	4.49 (1.35)	5.19 (1.14)	8.01	< .001	0.53
Total score	27.01 (5.24)	29.77 (4.75)	8.05	< .001	0.51

Table 8. Difference testing of pre-test and post-test OL scores for both control and experimental groups

Group	Learning topics	Pre-test *mean* (*SD*)	Post-test *mean* (*SD*)	*t*	*p*	Cohen's *d*
Control group (n = 997)	Marine leisure	5.56 (1.30)	5.89 (1.61)	10.13	< .001	0.32
	Marine society	6.36 (1.97)	6.49 (2.13)	4.36	< .001	0.14
	Marine culture	4.97 (1.39)	5.71 (1.61)	24.15	< .001	0.77
	Marine science and technology	3.87 (1.60)	4.43 (1.90)	17.09	< .001	0.54
	Marine resources and sustainability	4.02 (1.14)	4.49 (1.35)	15.84	< .001	0.50
	Total score	24.78 (5.03)	27.01 (5.24)	32.89	< .001	1.04
Experimental group (n = 289)	Marine leisure	5.46 (1.34)	6.45 (1.50)	16.51	< .001	0.97
	Marine society	6.22 (1.81)	6.66 (1.83)	14.83	< .001	0.87
	Marine culture	4.87 (1.34)	5.83 (1.38)	44.68	< .001	2.63
	Marine science and technology	3.81 (1.52)	5.63 (1.76)	25.53	< .001	1.50
	Marine resources and sustainability	4.15 (1.21)	5.19 (1.14)	20.42	< .001	1.20
	Total score	24.52 (4.47)	29.77 (4.75)	47.19	< .001	2.78

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ingful improvements in their OL scores from the pre-test to the post-test. However, the experimental group, which likely received more targeted instructional methods or learning activities, exhibited significantly greater gains, as evidenced by the larger effect sizes. This suggests the experimental treatments were effective in enhancing the students' knowledge and skills across the various marine-related topics covered in the study.

Conclusions and Discussion

This study evaluated the effectiveness of planning and implementing a school-based marine education curriculum in enhancing OL. The results reveal that students who completed the school-based marine education curriculum scored significantly higher in OL than did those in the control group. This demonstrates that the school-based curriculum effectively improved OL and highlights the importance of designing curricula considering local environmental and cultural characteristics.

The results of this study further indicate that implementing the school-based marine curriculum effectively enhanced students' understanding of and awareness regarding protecting the marine environment. This aligns with the findings of Chang et al. (2014), who suggested that implementing marine education significantly enhanced students' OL. In the current study, the experimental group's scores were significantly higher for the themes of marine leisure, marine science and technology, and marine resources and sustainability than those of the students in the control group. This demonstrates that specially designed curricula can promote student learning in these key domains.

The findings of the current study have significant educational implications. The authors attribute this difference to the variations in the design and content of the 16-week curriculum. Specifically, the curriculum for the experimental group included a diverse range of teaching strategies and topics, which not only enhanced student engagement but also strengthened their understanding of marine knowledge. The experimental group's curriculum incorporated activities related to marine leisure, such as beach clean-ups and water sports, which not only improved students' practical skills but also allowed them to learn the importance of marine ecology through interaction. This hands-on learning approach stimulated students' interest and promoted their understanding and appreciation of marine leisure activities. Additionally, the curriculum introduced experiments in marine science and technology, such as water quality analysis and ecosystem simulation, enabling students to grasp the fundamental principles of marine science through practical application. In contrast, the control group primarily relied on traditional lectures, lacking opportunities for hands-on experiences, which may have resulted in lower levels of engagement and interest in understanding these topics. Furthermore, the curriculum emphasized concepts of sustainable fisheries and marine protected areas, exploring the real-world significance of these issues through case studies. This in-depth investigation fostered a deeper understanding and concern for environmental issues among students, whereas the control group failed to provide such a comprehensive analysis, potentially leading to gaps in relevant knowledge.

However, it is noteworthy that no significant differences were observed between the two groups in the areas of marine society and marine culture. This may be due to the need for a deeper understanding of cultural background knowledge

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and social context related to these topics. Future curricula could consider incorporating field trips or community engagement activities related to marine society and culture, allowing students to directly experience and comprehend the diversity and significance of local marine cultures. In summary, these findings not only highlight the importance of specific topics in marine education but also indicate directions for future curriculum improvement. Educators should adjust their teaching strategies based on these findings to enhance students' marine literacy and promote their awareness and concern for the marine environment.

This study additionally highlighted the importance of teachers' professional knowledge. According to Lwo et al. (2013), teachers' marine knowledge and teaching abilities directly influence student learning outcomes. In the present study, most of the teachers involved in the intervention had a professional background in marine education, which may have contributed to the effectiveness of the curriculum. Teachers are not only transmitters of knowledge but also guides for students exploring marine topics. As such, teachers can stimulate student interest and motivation in learning about such topics.

The design of the current school-based curriculum enhanced students' motivation to learn and fostered concern and a sense of responsibility towards the marine environment. According to the United Nations SDGs, particularly SDG14, which involves the conservation and sustainable use of oceans and marine resources, OL is crucial in achieving global sustainable development. School-based marine education enables students to learn in real marine environments, which enhances their understanding and awareness of marine protection. This understanding is vital to future environmental conservation efforts.

According to the results of this study, schools should prioritize relevance and practicality when designing curricula for marine education programs. That is, schools should design school-based curricula that consider the local marine environment and cultural characteristics that incorporate, for example, field trips, community collaboration, and practical activities. Doing so can enhance students' and environmental awareness. Additionally, schools should provide opportunities for teacher professional development to help educators improve their marine knowledge and teaching skills and encourage them to integrate marine education with other subjects by designing interdisciplinary learning activities. This would not only stimulate students' interest in learning but also aid in providing them with an understanding of marine topics from multiple perspectives.

Schools should collaborate with environmental organizations, the local community, and the fishing industry to conduct marine conservation activities and field studies. This would enable students to gain OL through practical experiences and foster their sense of social responsibility. In addition, during the implementation of the marine education curriculum, schools should conduct regular assessments of student learning outcomes and use the results to adjust curriculum content to ensure its effectiveness and relevance continually.

Limitations and Future Research

This study has several limitations. First, the results may not be generalizable outside the region (and culture) in which the study was conducted. Second, this study was conducted over only one

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semester and, therefore, did not track the long-term changes in students' OL or the influence of the curriculum on their subsequent learning. Third, teaching styles and the level of student engagement may influence learning outcomes. However, these factors were not controlled for in this study. Fourth,, the sample ratio of the control group to the experimental group in this study is relatively high, and such an unbalanced design may introduce concerns regarding selection bias and the overall representativeness of the sample. This imbalance may limit the generalizability of the findings and could affect both internal and external validity. Future research should consider employing random assignment and maintaining more balanced group sizes to enhance the robustness of the results. Additionally, further investigations could explore the implications of group size on statistical power and the interpretation of outcomes in marine education studies.

Future studies can do the following to address these limitations. Studies can compare regions to explore the influence of marine education curricula on students' OL. This would help elucidate the influence of cultural background on learning outcomes. Additionally, studies can adopt a longitudinal design to assess the long-term effects of school-based marine education curricula on students' OL and analyze changes at different ages.

Future research could also explore more diverse assessment tools that are not subject to subjective influences to enhance the reliability and validity of evaluations. In addition, qualitative research methods, such as interviews with teachers and students regarding their experiences with and perceptions of marine education, could be employed to gain a deeper understanding of this topic. Moreover, studies can investigate effective means of enhancing teachers' professional development concerning marine education and evaluate the influence of different teaching strategies on student learning. Doing so would enable further optimization of the design and implementation of marine education curricula.

At the same time, future research should also consider incorporating additional covariates such as gender, socioeconomic status, or class-average academic achievement. Accounting for such factors could help mitigate any baseline inequities between the control and experimental groups, and further strengthen the persuasiveness of the findings. By including these covariates in the analysis, researchers can provide a more comprehensive understanding of the factors that may influence the effectiveness of the instructional interventions. This additional layer of analysis will be an important consideration as the research in this area continues to evolve and expand.

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Declaration of Conflicting Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

Baker, M. P., Bergstresser, D., Serafeim, G., & Wurgler, J. (2018). *Financing the response to climate change: The pricing and ownership of U.S. green bonds*. https://doi.org/10.2139/ssrn.3275327

Boaventura, D., Neves, A. T., Santos, J., Pereira, P. C., Luís, C., Monteiro, A., Cartaxana, A., Hawkins, S. J., Caldeira, M. F., & Ponces de Carvalho, A. (2021). Promoting ocean literacy in elementary school students through investigation activities and citizen science. *Frontiers in Marine Science*, *8*, Article 675278. https://doi.org/10.3389/fmars.2021.675278

Cava, F., Schoedinger, S., Strang, C., & Tuddenham, P. (2005). *Science content and standards for ocean literacy: A report on ocean literacy*. https://www.coexploration.org/oceanliteracy/documents/OLit2004-05_Final_Report.pdf

Cavas, B., Acık, S., Koc, S., & Kolac, M. (2023). Research trends and content analysis of ocean literacy studies between 2017 and 2021. *Frontiers in Marine Science*, *10*, Articel 1200181. https://doi.org/10.3389/fmars.2023.1200181

Chang, C.-C. (2015). 影響國中學生海洋科學知識與海洋教育能力指標因素之研究 [A study on the influential factors of marine science knowledge and capability indicators for junior high school students]. *Education Journal*, *43*(2), 173-196.

Chang, C.-C. (2019). Development of ocean literacy inventory for 16- to 18-year-old students. *sage Open*, *9*(2), 1-15. https://doi.org/10.1177/2158244019844085

Chang, C.-C., Yang, W.-C., & Lwo, L.-S. (2014). 高職生海洋科學素養與迷思概念之評量分析[Evaluating vocational high school students' marine science literacy and their misconceptions]. *Science Education Monthly*, 371, 2-17. https://doi.org/10.6216/SEM.201408_(371).0001

Fauville, G., Strang, C., Cannady, M. A., & Chen, Y.-F. (2019). Development of the international ocean literacy survey: Measuring knowledge across the world. *Environmental Education Research*, *25*(2), 238-263. https://doi.org/10.1080/13504622.2018.1440381

Fielding, S., Copley, J. T., & Mills, R. A. (2019). Exploring our oceans: Using the global classroom to develop ocean literacy. *Frontiers in Marine Science*, *6*, Article 340. https://doi.org/10.3389/fmars.2019.00340

French, V., Chu, N.-C, Santoro, F., Sousa Pinto, I., Borges, D., & McDonough, N. (2015). *Review of ocean literacy in European maritime policy*. https://www.marineboard.eu/sites/marineboard.eu/files/public/publication/D5.1Review_of_Ocean_Literacy_in_Governance.pdf

Glithero, L. D., Bridge, N., Hart, N., Mann-Lang, J., McPhie, R., Paul, K., Peebler, A., Wiener, C., Yen, C., Kelly, R., McRuer, J., Hodgins, D., & Curtin, F. (2024). *Ocean decade vision 2030 white papers—Challenge 10: Restoring society's relationship with the ocean*. AquaDocs. https://doi.org/10.25607/ekwn-wh61

Glithero, L. D., & Zandvliet, D. B. (2021). Evaluating ocean perceptions and ocean values: The Canadian

airiti

ocean literacy survey. *Canadian Journal of Environmental Education*, *24*(1), 216-232.

Guest, H., Lotze, H. K., & Wallace, D. (2015). Youth and the sea: Ocean literacy in Nova Scotia, Canada. *Marine Policy*, *58*, 98-107. https://doi.org/10.1016/j.marpol.2015.04.007

Halversen, C., & Schoedinger, S., & Payne, D. (Eds.). (2021). *A handbook for increasing ocean literacy: Tools for educators and ocean literacy advocates*. https://www.noaa.gov/handbook-for-increasing-ocean-literacy

Intergovernmental Oceanographic Commission of United Nations Educational, Scientific and Cultural Organization. (2021a). *Ocean literacy within the United Nations decade of ocean science for sustainable development: A framework for action*. https://unesdoc.unesco.org/ark:/48223/pf0000377708.locale=en

Intergovernmental Oceanographic Commission of United Nations Educational, Scientific and Cultural Organization. (2021b). *The United Nations decade of ocean science for sustainable development (2021-2030): Implementation plan*. https://formas.se/download/18.4a51d3151799e35bc3b16525/1622211608373/ImplementationPlan_April2021.pdf

Lwo, L.-S., Chang, C.-C., Tung, Y.-P., & Yang, W.-C. (2013). 高中生海洋科學素養及迷思概念評量分析 [Marine science literacy and misconceptions among senior high school students]. *Journal of Research in Education Sciences*, *58*(3), 51-83. https://doi.org/10.6209/JORIES.2013.58(3).03

Ministry of Education. (2014). 十二年國民基本教育課程綱要一總綱 [Curriculum guidelines of 12-year basic education: General guidelines]. https://reurl.cc/kMkkN3

Ministry of Education. (2020). 十二年國民基本教育課程綱要一議題融入說明手冊 [Curriculum guidelines of 12-year basic education: Guidelines for issue integration].

Markos, A., Boubonari, T., Mogias, A., & Kevrekidis, T. (2017). Measuring ocean literacy in pre-service teachers: Psychometric properties of the Greek version of the Survey of Ocean Literacy and Experience (SOLE). *Environmental Education Research*, *23*(2), 231-251. https://doi.org/10.1080/13504622.2015.1126807

Miller, D. D., Ota, Y., Sumaila, U. R., Cisneros-Montemayor, A. M., & Cheung, W. W. L. (2018). Adaptation strategies to climate change in marine systems. *Global Change Biology*, *24*(1), e1-e14. https://doi.org/10.1111/gcb.13829

Mogias, A., Boubonari, T., Realdon, G., Previati, M., Mokos, M., Koulouri, P., & Cheimonopoulou, M. T. (2019). Evaluating ocean literacy of elementary school students: Preliminary results of a cross-cultural study in the mediterranean region. *Frontiers in Marine Science*, *6*, Article 396. https://doi.org/10.3389/fmars.2019.00396

Mokos, M., Realdon, G., & Cižmek, I. Z. (2020). How to increase ocean literacy for future ocean sustainability? The influence of non-formal marine science education. *Sustainability*, *12*(24), Article 10647. https://doi.org/10.3390/su122410647

National Oceanic and Atmospheric Administration. (2013). *Ocean literacy: The essential principles and fundamental concepts of ocean sciences for learners of all ages (version 2)*. https://repository.library.

airiti

noaa.gov/view/noaa/39086/noaa_39086_DS1.pdf

National Oceanic and Atmospheric Administration. (2020). *Ocean literacy: The essential principles and fundamental concepts of ocean sciences for learners of all ages (version 3)*. https://cdn.oceanservice.noaa.gov/oceanserviceprod/education/literacy/ocean-literacy-english.pdf

Paredes-Coral, E., Mokos, M., Vanreusel, A., & Deprez, T. (2021). Mapping global research on ocean literacy: Implications for science, policy, and the blue economy. *Frontiers in Marine Science*, *8*, Article 648492. https://doi.org/10.3389/fmars.2021.648492

Plankis, B. J., & Marrero, M. E. (2010). Recent ocean literacy research in United State public schools: Results and implications. *International Electronic Journal of Environmental Education*, *1*(1), 21-51.

Steel, B. S., Smith, C., Opsommer, L., Curiel, S., & Warner-Steel, R. (2005). Public ocean literacy in the United States. *Ocean & Coastal Management*, *48*(2), 97-114. https://doi.org/10.1016/j.ocecoaman.2005.01.002

Tsai, L.-T. (2019). Multilevel effects of student and school factors on senior high school students‘ ocean literacy. *Sustainability*, *11*(20), Article 5810. https://doi.org/10.3390/su11205810

Tsai, L.-T., & Chang, C.-C. (2024). Relationships between high school students' learning interest, learning motivation, and ocean literacy: A longitudinal study. *Environmental Education Research*, *31*(6), 1154-1165. https://doi.org/10.1080/13504622.2024.2428923

Tsai, L.-T., Sasaki, T., Wu, C.-K., & Chang, C.-C. (2023). Ocean literacy among Taiwanese and Japanese high school students. *Marine Policy*, *150*, Article 105555. https://doi.org/10.1016/j.marpol.2023.105555

United National. (n. d.). *Goal 14: Conserve and sustainably use the oceans, seas and marine resources*. https://www.un.org/sustainabledevelopment/oceans/

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跨學科校本海洋教育課程對高中生海洋素養之影響評估

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摘要

本研究旨在評估校本海洋教育課程對提升高中生海洋素養之成效，透過課程設計探討其對學生海洋素養的影響。研究對象為 1,284 名高中一年級學生，分為實驗組 (287 名) 與對照組 (997 名)。實驗組學生參與為期 16 週的校本海洋教育課程，對照組則於一般學科課程中融入海洋教育相關主題。兩組學生分別接受課程前後的海洋素養測驗 (前測與後測)。本研究所使用之海洋素養問卷，依據臺灣十二年國民基本教育課程綱要海洋教育內容設計而成，涵蓋五大學習主題，共計 40 題。該問卷經驗證具有良好的信度與效度 (內容效度、聚合效度與建構效度)，項目反應理論分析顯示題項難度範圍介於 -3.157 ~ 1.564，屬於適中偏易的測驗工具。結果顯示，實驗組與對照組在前測時並無顯著差異 (t = 0.79, p = .429)；兩組學生在後測的海洋素養成績則均顯著提升，且實驗組的平均分數 (29.77) 顯著高於對照組 (27.01) (t = 8.02, p < .001, Cohen's d = 0.54)。此外，實驗組在海洋休閒、海洋科技與海洋資源永續利用等項目上的表現亦顯著優於對照組。本研究證實校本海洋教育課程能有效提升學生的海洋素養，建議學校在課程設計時應重視其實踐性與在地性，並提供教師專業發展機會，以進一步促進學生的海洋素養提升。

關鍵詞：永續發展、校本課程、海洋素養、海洋教育、學生學習成效

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