Marine Research
of the National Academy of Marine Research
ISSN: 2709-6629 (Vol.3 Iss.1)
GPN: 2011200033

DOI: http://dx.doi.org/10.29677/MR.202306_3(1).0001
2023, 3(1), 1-20

Development of a Scale to Measure the Effectiveness of Marine Science Learning for Primary School Students

Chia-Dai (Ray) Yen [1*] Wen-Yi Lee [2] Tsuyoshi Sasaki [3] Yasuyuki Kosaka [4]

[1] Graduate Institute of Education, National Taiwan Ocean University, Keelung, Taiwan
[1] Planning and Training Center, National Academy of Marine Research. Kaohsiung, Taiwan
[2] Keelung Municipal Hsin Yi Elementary School, Keelung, Taiwan
[3] Department of Marine Policy and Culture, Tokyo University of Marine Science and Technology, Tokyo, Japan
[4] Department Marine Science, Wakasa High School, Fukui Prefectural, Japan

ABSTRACT

This study aims to develop a comprehensive marine science learning effectiveness scale to measure attitudes and skills related to ocean literacy and evaluate marine science learning activities. It utilizes data from the National Science Week-Ocean Fun Learning Activity and employs the Grounded Theory process to extract concepts through interviews with students, curriculum designers, and education experts. The validity of the questionnaire was established through a pilot study using exploratory and confirmatory factor analysis. The resulting marine science learning effectiveness scale consists of eight subscales and 29 questions. The research findings were utilized to construct a marine science learning effectiveness scale, consisting of eight subscales: "ocean science," "ocean influence," "marine ecology," "marine resources management," "ocean stewardship," "marine awareness," "education promotion," and "problem solving." The scale comprises a total of 29 questions. In the future, this scale can be applied as a criterion for evaluating the effectiveness of various marine science activities and to accumulate achievements in marine science education.

Keywords: Marine science learning effectiveness, scale development, Grounded Theory, Delphi, ocean literacy.

* Corresponding author, e-mail: hamrater@msn.com

Received 13 July 2023, Accepted 26 September 2023.

1 INTRODUCTION

Over the past 50 years, marine education has experienced significant development on an international level. In 2000, researchers and educators in marine science at the University of Southern Mississippi gathered to discuss marine scientific literacy and address the educational challenges faced by the United States. To tackle these issues effectively, suggestions were provided by the National Science Foundation and other federal agencies to establish the Centres for Ocean Sciences Education Excellence (COSEE) network. This network serves as a platform for marine science education and resources across all grade levels. The COSEE network, connecting marine science researchers, educators, and the public, has played a vital role in disseminating knowledge and fostering ocean literacy. By enhancing public awareness of marine science and providing a formal definition of ocean literacy, it promotes a better understanding of the ocean's significance and encourages responsible actions towards its conservation (Schoedinger et al., 2006). Ocean literacy is defined as the understanding of the ocean's influence on you and your influence on the ocean (Fauville et al., 2019; Dupont & Fauville, 2017; Borja et al., 2020; McKinley et al., 2023). It encompasses seven principles:

1. The Earth has one big ocean with many features.
2. The ocean and life in the ocean shape the features of Earth.
3. The ocean is a major influence on weather and climate.
4. The ocean made the Earth habitable.
5. The ocean supports a great diversity of life and ecosystems.
6. The ocean and humans are inextricably interconnected.
7. The ocean is largely unexplored.

During the Ocean Conference on June 8, 2017, UNESCO highlighted the importance of scientific understanding of the ocean as the foundation for effectively managing human activities that impact the marine environment and communities (Valdés, 2017). Scientific understanding enables prediction and guides society in adapting to the ocean's diverse impacts on human life and infrastructure across different spatial and temporal scales. It facilitates pollution prevention, cleanup efforts, marine spatial planning, and the protection of marine ecosystems. Additionally, the UN Conference on the Law of the Sea establishes a legal framework for marine scientific research. It mandates countries and competent international organizations to promote the development, conduct, and international cooperation in marine scientific research (Salpin et al., 2018; Doussis, 2017). However, people have very limited knowledge about the ocean, and because of this limited understanding, they cannot grasp the importance of the ocean, find it difficult to comprehend the challenges the ocean faces, and struggle to generate motivation for positive actions towards it (Brennan et al., 2019).

Education plays a vital role in fostering the sustainable development of the ocean. It is essential to start cultivating ocean awareness in students from elementary school and encourage them to take tangible actions for its protection. Marine education should continue to be integrated into public primary and secondary schools. However, despite its significance, marine-related content in school textbooks remains scarce, indicating a lack of sufficient dissemination of ocean-related knowledge in educational settings (Gough, 2017; Mokos et al., 2020). This insufficiency not only highlights a lack of public awareness regarding the ocean, but also emphasizes the need for more comprehensive measurement of ocean literacy.

Marine Research of the National Academy of Marine Research
DOI: 10.29677/MR.202306_3(1).0001

Currently, ocean literacy measurement primarily focuses on cognitive aspects, while the measurement of attitudes and skills is still insufficient (Lambert, 2006; Fauville et al., 2019; Tsai & Chang, 2019; Tsai et al., 2019; Mogias et al., 2019; Lin et al., 2020). Although ocean literacy is a crucial factor influencing marine environmental awareness, many studies emphasize the importance of attitudes and pro-environmental behaviors in responding to environmental issues (Winks, Ward, Zilch, & Woodley, 2020). There is a growing recognition of the significance of emotional components in learning, and prior attitudes and beliefs are often more influential than mere knowledge in determining learners' behavioral outcomes (Heimlich et al., 2012).

The objectives of primary education encompass motivating learning, cultivating curiosity, exploration, critical thinking, judgment, and action, fostering an active attitude, developing attitudes and ongoing motivation for exploration and learning, experiencing the joy of learning, and instilling a sense of self-worth. These goals aim to stimulate individuals' potential for healthy and personal development (Shernoff & Csikszentmihalyi, 2009; Ostroff, 2016). This perspective signifies a shift away from passive knowledge acquisition towards active engagement with real-life applications and experiences, reflecting the principles of experiential learning advocated by Dewey (1986). Recognizing the uniqueness of each student and their diverse learning paths, it is important not to impose uniform standards and benchmarks on all students. Instead, educators should embrace and respect diversity while promoting adaptive development and empowering students to discover their own career paths. The teacher's role has evolved from simply imparting knowledge and skills to facilitating independent learning. In this context, marine education aims to help students understand the ocean, cultivate positive attitudes and skills towards the ocean environment, and integrate this knowledge into their daily lives.

This study aims to develop a scale with good reliability and validity specifically designed to assess marine science learning effectiveness among elementary school students. The expanded scale can serve as a valuable tool for evaluating the effectiveness of marine science education. It can also provide education authorities, schools, marine science museums, and teachers with a reference for assessing marine science learning effectiveness in elementary school settings.

2 LITERATURE REVIEW

Lambert's article (2005) provided a comprehensive overview of marine science concepts. The article discussed various areas within marine science, including marine physics, marine geology, meteorology, air-sea interaction, marine biology, marine chemistry, humans and the marine environment, as well as ocean-related technologies that benefit humanity. In 2017, the 'Global Ocean Science Report' by UNESCO categorized marine science into seven distinct fields. UNESCO's proposal, 'The Ocean We Need for the Future We Want,' emphasized that advancements in marine technology can enhance human understanding of the ocean, gather data on marine pollution, improve the marine environment and ecosystems, facilitate interregional and interdisciplinary cooperation among countries, and foster continued growth in the marine economy (Valdés, 2017).

Marine science is a multidisciplinary scientific field that encompasses the study of the marine environment and its interactions with the entire Earth ecosystem (Lambert, 2005; 2006). In 2012, the attendees of the Rio+20 conference published 'The Future We Want' (United Nations, 2012), which emphasized the importance of establishing an institutional framework for sustainable development, particularly focusing on ocean issues. The document highlighted the need to utilize ocean science to protect and sustainably utilize the ocean and its resources, as well as to monitor and address ocean acidification.

DOI: 10.29677/MR.202306_3(1).0001

Climate change has significant effects on human life and has led to the severe degradation of marine ecosystems globally. It is crucial to employ ocean science to understand the ongoing changes in the ocean and mitigate their adverse impacts. Recognizing the importance of ocean science, the United Nations declared 2021-2030 as the Decade of Ocean Science for Sustainable Development (Guan et al., 2023). This initiative aims to address marine knowledge gaps and promote the sustainable use of marine resources through the implementation of six goals over the course of ten years. The objectives of the Decade of Ocean Science for Sustainable Development include:

1. Enhancing ocean science for sustainable development: Promoting research and innovation to improve our understanding of the ocean and its role in sustainable development.

2. Improving ocean health: Developing strategies and measures to restore and maintain the health and resilience of marine ecosystems, including addressing pollution, habitat destruction, and overfishing.

3. Enhancing the sustainable use of ocean resources: Promoting sustainable fishing practices, aquaculture, and responsible ocean resource extraction while minimizing negative environmental impacts.

4. Strengthening ocean observations and data exchange: Expanding global ocean monitoring systems, enhancing data sharing, and improving access to ocean data to support informed decision-making.

5. Enhancing coastal resilience and adaptation: Developing strategies to address the impacts of climate change, rising sea levels, and extreme weather events on coastal communities and ecosystems.

6. Fostering ocean literacy and awareness: Promoting public understanding of the importance of the ocean, its ecosystems, and the need for sustainable ocean management through education and outreach programs.

The Decade of Ocean Science for Sustainable Development aims to achieve the following objectives to promote scientific collaboration, advance our understanding of the ocean, and provide the knowledge and tools necessary for the sustainable management of marine resources and the conservation of marine ecosystems:

1. Strengthening the sustainable use of marine resources: By implementing sustainable practices, such as responsible fishing and responsible resource extraction, the goal is to ensure the long-term viability of marine resources while minimizing negative environmental impacts.

2. Collecting scientific data to manage the use of marine resources: Gathering comprehensive and accurate data on marine ecosystems is crucial for effective resource management and decision-making. This includes monitoring biodiversity, assessing the health of ecosystems, and understanding the impacts of human activities.

3. Supporting the development of the marine economy: By promoting sustainable practices and innovation, the Decade of Ocean Science for Sustainable Development aims to foster the growth of a thriving and sustainable marine economy. This includes supporting industries such as fisheries, aquaculture, and tourism, while ensuring their activities are environmentally responsible.

4. Managing coastal ecosystems: Coastal areas are highly vulnerable to climate change and human activities. Effective management of coastal ecosystems, including mangroves, coral reefs, and wetlands, is vital for protecting biodiversity, mitigating climate change impacts, and safeguarding coastal communities.

Marine Research of the National Academy of Marine Research
DOI: 10.29677/MR.202306_3(1).0001

5. Increasing ocean science: The Decade of Ocean Science for Sustainable Development seeks to expand our understanding of the ocean through research, exploration, and knowledge-sharing. This includes advancing scientific methodologies, exploring unexplored areas of the ocean, and studying key processes and phenomena.

6. Sharing resources: Collaboration and sharing of resources, including data, technologies, and expertise, are essential for maximizing the impact of ocean science. By fostering international cooperation and partnerships, the Decade of Ocean Science for Sustainable Development aims to enhance collective efforts towards sustainable ocean management.

Recognizing the crucial role of elementary school education in laying the foundation for marine knowledge conservation, it is imperative to enhance marine knowledge and research capabilities (Lin et al., 2020). Given that the ocean remains largely unexplored, investing in marine education becomes paramount to promoting awareness and understanding among future generations. To achieve this, teaching methods should adopt a learner-centered approach, where teachers comprehend students' learning modes and tailor their instruction accordingly (Lam, 2018; Chauhan, 2017). High-quality teaching entails efficient allocation of teaching time and the implementation of effective classroom strategies. By integrating marine education into elementary schools, we can foster a sense of environmental stewardship and actively contribute to the sustainable management of marine resources.

Assessing the effectiveness of learning encompasses evaluating the quality of teaching and the degree of student learning (Boston & Candela, 2018). Consequently, numerous scholars have developed scales or questionnaires to gauge students' effective learning within a curriculum (Vidergor, 2018; Chou et al., 2019). The marine science learning effectiveness scale employed in this study aimed to measure changes in cognition, attitude, and skills. The scale needs rigorous reliability and validity testing to ascertain whether students experienced changes in cognition, attitude, and skills following the learning process, and whether internal or external factors influenced learning effectiveness. Markos et al. (2015) created the Greek version of the Survey of Ocean Literacy and Experience (SOLE), which demonstrated strong psychometric properties when used to assess ocean literacy in pre-service teachers. This indicates that the instrument effectively measures the levels of ocean knowledge, understanding, and familiarity among this specific group. Subsequently, Chang (2019) developed a 48-item Chinese version ocean literacy scale for Taiwanese high school students. Meanwhile, Fauville et al. (2019) developed the International Ocean Literacy Survey (IOLS) and surveyed 16-18 years old high school students in 24 countries across 17 languages. Beside the quantitative methods, Lin et al., (2020) involved surveying ocean literacy and the usage of ocean-related terms among students from seven middle schools, aiming to compile commonly used ocean-related vocabulary and accurate perceptions of the ocean as indicators of ocean literacy. Lin et al. (2019) used the marine science learning motivation (MSLM) inventory, the marine science learning interest (MSLI) inventory, and the marine science learning achievement (MSLA) inventory, to examine the impact of game-based marine science learning on high school students' performance in marine science.

However, while these studies primarily focus on ocean literacy, their main participants are mostly teachers and secondary school students who have more direct exposure to marine science through subjects like earth science, biology, and physics in their secondary school curriculum. In contrast, primary school curricula tend to incorporate marine science topics to a lesser extent, emphasizing integration with broader issues and including less specialized knowledge about marine science. Furthermore, there is often more non-curricular learning content at the primary school level. Therefore, this study aims to develop an ocean science learning scale through marine science activities. It is intended to serve as a foundational tool for assessing the effectiveness of promoting marine science activities, particularly in primary school settings, where the emphasis is on integrating marine science content into broader educational objectives.

3 RESEARCH METHODS

3.1 Concept construction

This research employed the Grounded Theory method, which involved open coding, axis coding, and selective coding, to analyze data from interviews, lesson plan content, and observations of marine science activities. The aim was to enhance understanding of social interactions, processes, and changes from educators' perspectives. Key concepts were extracted and categorized, resulting in 287 concepts that were further grouped into 36 subcategories. Through selective coding, connections between main categories were identified, and a core category was established. The analysis identified 31 categories, including eight cognitive categories such as marine ecology and marine biological knowledge, and multiple subcategories within them. The attitude dimension included categories like active learning and environmental protection awareness, while the skills dimension encompassed categories such as problem solving and interpersonal interaction. These categories represent a diverse range of skills and attitudes relevant to marine science education.

3.2 Delphi to confirm the construct

A conceptual framework was constructed, and three rounds of the Delphi method were conducted to ensure expert consensus. The panel of experts comprises two university education professors specializing in marine education and one research officer who is responsible for marine science education and serves as the head of a marine science and technology museum. The factors were compiled into a marine science learning effectiveness scale. Experts provided input through questionnaire reviews, resulting in the revision and refinement of 23 categories. The second stage involved scoring categories to establish the scale's scope, with consistent high ratings leading to the retention of all 23 categories. The third stage focused on developing learning indicators aligned with clear and achievable knowledge based on the Ocean Literacy Scope and Sequence for Grades K–12. The cognitive level aligned with the ocean literacy learning index, while the attitude and skill aspects did not align.

3.3 Lesson plans

This study primarily focused on the National Museum of Marine Science and Technology's "Ocean FUN Learning Program." At that time, the program offered four modules comprising 12 sets of marine-related thematic activities for students in the third grade and above. Module A included (1) understanding current management measures for crab fisheries and the importance of sustainable oceans, (2) grasping the principles of buoyancy and the concepts of load capacity and low ship density, and (3) gaining insights into coral reef biodiversity and marine species classification. Module B covered (4) understanding the impacts of human activities, climate change, and biological competition on coral reef survival, (5) exploring the relationship between the center of gravity and landing position of underwater gliders based on buoyancy principles, and (6) recognizing the items required for beach cleaning and the significance of beach cleaning for marine conservation. Module C consisted of (7) understanding the principles of deep-sea mineral exploration, (8) exploring coral reef biodiversity and marine species classification, and (9) recognizing the significance represented by barcodes and understanding the importance of beach cleaning for marine conservation. Lastly, Module D included (10) getting acquainted with wave power generation and the Wells turbine, (11) comprehending the relationship between fish classification and habitat-specific fish characteristics, and (12) recognizing the importance of biodiversity in maintaining ecological balance. These four major modules with 12 courses each were all rooted in marine science. Each activity lasted approximately 10 minutes and allowed participants to experience multiple different challenges within a single time frame.

DOI: 10.29677/MR.202306_3(1).0001

3.4 Pilot study

The pilot study aimed to refine the questionnaire items, retain high-quality items, and construct an appropriate scale model. The study involved 94 students from third to sixth grade who participated in a National Science Week module teaching plan provided by the National Museum of Marine Science and Technology (NMMST). Item analysis and exploratory factor analysis were conducted to assess item suitability. Several indicators were evaluated for each question, including the percentage of missing values, mean, item variance, item skewness coefficient, independent-sample t-test, correlation with the revised items and total score, and α coefficient after item deletion. Based on these indicators and the analysis of items using a five-point Likert scale, poor-quality items were removed. During the pilot study, questions were deleted if two out of three indicators (item discrimination, correlation, and Cronbach α) were poor or if three out of four indicators (percentage of missing values, item average, item variance, and item skewness coefficient) were low. Question 19 ("I will participate in activities related to waters") was deleted due to unacceptable results in t-test, correlation, and α coefficient. Ultimately, 29 items met the criteria and were retained for further analysis.

Table 1. Pilot study sample.

	3rd Grade	4th Grade	5th Grade	6th Grade	Total
Male	13	11	15	11	50
Female	12	9	12	11	44
Total	25	20	27	22	94

3.5 Exploratory factor analysis

Principal component extraction was employed for the exploratory factor analysis of the pilot study scale. Factors were extracted based on eigenvalues greater than one, using the axis method to identify the factors with maximum variance and simplify the factor structure. The scale consisted of three major dimensions: cognition, attitude, and skills, which were subjected to exploratory factor analysis. The Kaiser-Meyer-Olkin (KMO) and Bartlett's test values for the three dimensions exceeded the threshold of 0.70, indicating common factors among the variables. This confirmed the suitability of the scale for exploratory factor analysis. In terms of cognitive variables, four facets were identified with eigenvalues greater than one. Each facet contained three to four questions, and the judgment of each question was classified based on the factor with the highest loading. The total variance explained by these factors was 59%.

For attitude variables, the exploratory factor analysis revealed one factor with a loading of 0.474 for item A6, slightly lower than the standard of 0.50 but still within an acceptable range. Item A6, which focused on the concept of marine environmental protection, was temporarily retained due to its relevance to marine science learning. Regarding skill variables, one factor with an eigenvalue greater than one was identified. However, due to the large number of skill-related questions, a second exploratory factor analysis was conducted to force the division of dimensions into two factors, resulting in a cumulative variation exceeding 60%.

Table 2. Component matrix of factor analysis.

Item	Factors				Item	Factors	Item	Factors	
	1	2	3	4		1		1	2
K8	.781				A1	.814	S7	.785	
K7	.674				A7	.802	S8	.740	
K6	.580				A4	.784	S2	.698	
K10		.787			A3	.749	S1	.661	
K11		.718			A8	.730	S5		.830
K9		.594			A2	.698	S6		.795

Item	Factors				Item	Factors	Item	Factors	
	1	2	3	4		1		1	2
K12		.587			A6	.474	S4		.676
K1			.777				S3		.627
K2			.776						
K3			.576						
K4			.568						
K5				.805					
K14				.594					
K13				.438					
Eigenvalues	4.322	1.525	1.244	1.173	Eigenvalues	3.725	Eigenvalues	4.112	.957
Explained variance %	30.875	10.895	30.875	10.895	Explained variance %	53.219	Explained variance %	51.403	11.966
Cumulative explained variance %	30.875	41.770	50.657	59.033	Cumulative explained variance %	53.219	Cumulative explained variance %	51.403	63.369

Note: 1. Extraction Method: Principal Component Analysis. 2. Rotation Method: Varimax with Kaiser Normalization. 3. The code "K" represents cognition, "A" represents affect, and "S" represents skills.

This study synthesized concepts related to the effectiveness of learning marine science through interviews, observations, and literature review. The concepts were organized and named during the process, with specific definitions assigned to "ocean" and "marine." "Ocean" refers to concepts primarily focused on the ocean itself, while "marine" encompasses all related concepts pertaining to the ocean. Therefore, concepts related to marine science specifically emphasize the ocean (ocean-related), while broader awareness concepts or those covering abstract aspects are primarily categorized as marine-related. After the exploratory factor analysis, the seven dimensions were defined according to the concepts and commonality.

1. *Ocean science:* Ocean science refers to physical oceanography, geological oceanography, meteorological interaction between the ocean and the atmosphere, biological oceanography, chemical oceanography, humanities, and the marine environment, and ocean-related issues that are beneficial to humans, as described by Lambert (2005). Based on the framework of ocean literacy in the 3-5 scope and sequencing concepts, the ocean science factor is summarized as four concepts, including the main factors influencing the formation of ocean currents, the causes of seawater salinity and pressure, seafloor topography, and oceanic circulation. (Schoedinger et al., 2010).

2. *Ocean influence:* According to the definition of ocean literacy, this research defined ocean influence as a force characteristic of the ocean that influences human life (Santoro et al., 2018). The concept of ocean literacy primarily focuses on understanding the impact of the ocean on humans. Within this framework, three key concepts include climate change, the ocean's role in oxygen production and carbon dioxide absorption, and the relationship between the ocean and humans (Hilmi et al., 2021).

3. *Marine ecology:* Marine ecology collects marine-related environments and organisms, which involve concepts such as the marine food web, the relationship between marine organisms and their environment, and marine ecosystems and habitats (Zhang, Yuan, & Kim, 2023).

4. *Marine resource management:* The sustainable use of marine resources must increase economic development while maintaining the natural environment (Awan, 2013). The concepts include legal protection for marine organisms, marine protected areas, marine debris, and the regeneration of marine resources.

DOI: 10.29677/MR.202306_3(1).0001

5. *Ocean stewardship:* Ocean stewardship is defined as an understanding of changes in the marine environment, a willingness to assume responsibility for protecting the ocean, and active participation in ocean protection (Yen & Sembiring, 2020). The concepts include the willingness to learn about marine science and related matters, an interest in understanding marine science, and the willingness to donate money or other resources to support marine environmental issues.

6. *Educational promotion:* In this research, educational promotion is the ability to convey knowledge through speech or action, directly or indirectly influencing the ideas of others (Warwick, Linfield, & Stephenson, 1999). The concepts include the ability to lead others in discussing marine-related issues, the ability to share discovered ocean problems, the ability to gather information about marine topics, and the ability to share marine-related issues with others.

7. *Problem solving:* Problem solving is a necessary primary education ability and is defined as using one's previous experience, knowledge, skills, and understanding to think, explore, and reason to meet the needs of unresolved unfamiliar situations (Cheng et al., 2017). The concepts include identifying marine-related issues, proposing solutions, applying learned knowledge to problem solving, finding appropriate solutions, and communicating problem solving approaches with others.

This study further analyzed the scale's reliability and validity by using Cronbach's α, which must be >0.70 for the overall scale and >0.50 for the subscales. Analytical results were obtained in the three dimensions of cognition, attitude, and skills. The seven factors' reliability values were >0.50, and the overall reliability was 0.919, indicating that the scale had suitable internal consistency.

4 RESULTS AND DISCUSSION

This study utilized a scale to assess the effectiveness of marine science learning during the National Science Week activities organized by the NMMST. The scale's content validity was evaluated by experts, and a preliminary scale was developed. Following a pilot study, item analysis and exploratory factor analysis were conducted to refine the scale. The NMMST provided six lesson plans to two randomly selected elementary schools, where questionnaires were distributed and collected. A total of 372 valid responses were collected from four randomly sampled elementary schools that participated in the activities. A table showing the sample cross-analysis of gender and age is as follows:

Table 3. Sample Cross-analysis of Gender and Age.

	3rd Grade	4th Grade	5th Grade	6th Grade	Total
Male	30	36	65	68	199
Female	26	34	61	52	173
Total	56	70	126	120	372

4.1 Reliability

This study assessed the effectiveness of marine science learning among grade 3-6 students during the National Science Week organized by the NMMST. The marine science learning effectiveness scale had three dimensions: cognition, attitude, and skills. The reliability of the dimensions ranged from 0.894 to 0.935, exceeding the threshold of 0.7. The overall reliability of the scale was 0.962, indicating good reliability.

DOI: 10.29677/MR.202306_3(1).0001

Table 4. Factor Reliability.

Constructs	Factors	Item N	Factor Reliability	Reliability
Cognition	Ocean science	3	.794	.935
	Ocean influence	4	.849	
	Marine ecology	4	.849	
	Marine resource management	3	.796	
Attitude	Ocean stewardship	7	.894	.894
Skill	Education promotion	4	.864	.920
	Problem solving	4	.878	

4.2 Confidence intervals

This study calculated 95% confidence intervals (CIs) to determine if the α coefficients of the overall scale and each aspect significantly differed from 0.70. The F test result showed F (371, 10,388) = 7.974, with p = .000. Since p < .001, the null hypothesis could be rejected, indicating that α was significantly greater than 0.70. The 95% CI for the overall scale was 0.957–0.968.

Table 5. Confidence intervals test.

Variables	Factors	Confidence Interval		F value	*p* value
		Lower	Upper		
Cognition	Ocean science	.755	.828	1.458	.000***
	Ocean influence	.822	.872	1.982	.000***
	Marine ecology	.823	.873	1.991	.000***
	Marine resource management	.757	.830	1.472	.000***
Attitude	Ocean stewardship	.877	.910	2.827	.000***
Skill	Education promotion	.839	.885	2.199	.000***
	Problem solving	.856	.897	2.451	.000***
Total		.957	.968	7.974	.000***

*Note: ***p<0.001*

4.3 Confirmatory factor analysis

The exploratory factor analysis provided the theoretical basis for this study, while the confirmatory factor analysis examined the validity of the theory. A path diagram was created using AMOS statistical software to illustrate the relationships between factors, factors and topics, error variables, and connections. The scale analysis resulted in a χ^2 value of 981.425, which was statistically significant (p<0.05). However, it is important to consider the χ^2/df ratio (χ^2 value divided by degrees of freedom), with a ratio of 2.757 in this research model, below the threshold of 3.0 as suggested by Bagozzi et al. (1998). Other fit indicators were reviewed to evaluate the model's fit. The adjusted goodness of fit index (AGFI) did not reach the threshold of 0.80. Although the normed fit index (NFI), relative fit index (RFI), and goodness of fit index (GFI) were above 0.80, they did not meet the threshold of 0.90. Therefore, this model requires further adjustments.

Marine Research of the National Academy of Marine Research
DOI: 10.29677/MR.202306_3(1).0001

4.3.1 Inherent structural fit of the model

The model's structural fit was evaluated based on factor loads, amount of variation, and standardized residual values of factors and items. The evaluation criteria included explained variance, composite reliability (CR), and average variance extracted (AVE). Fornell and Larcker (1981) suggested the following standards: CR should exceed 0.7, standardized factor loadings should be above 0.5 and statistically significant, and an AVE higher than 0.5. CR represents the internal consistency of construct indicators, and a threshold of 0.7 is considered acceptable. The AVE indicates the variance explained by the observed variables. Bagozzi et al. (1998) recommended R2 to be above 0.25, CR to exceed 0.6, and AVE to surpass 0.5 for a good structural fit. The analytical results of this study were assessed against these criteria. The R^2 values for the 29 items in the scale ranged from 0.37 to 0.70. The CR values for the seven factors were between 0.75 and 0.80, surpassing the threshold of 0.7. However, the AVEs for marine ecology, marine resource management, and problem solving fell below 0.5, indicating the need for revision of those items.

4.3.2 Model modification

To address model suitability issues, the collected data and constructed theory were evaluated, leading to the adoption of correction methods. In this study, a first correction method was applied, which involved simplifying the questions in the developed model. Exploratory factor analysis was conducted to determine if adjustments were necessary for each item's dimensions. The overall exploratory factor analysis results indicated a suitable KMO value of 0.961, and Bartlett's test confirmed the appropriateness of the questionnaire for exploratory factor analysis. Consistent with the pilot study, the analysis revealed that certain questions belonged to the same factors, while others formed different factors. To further analyze these discrepancies, the three dimensions were examined separately to identify common factors among the questions. The cognitive dimension was divided into four factors: *ocean science, ocean influence, marine ecology, and marine resource management,* with KMO and Bartlett's test results of 0.945 and 3031.403, respectively. The attitude dimension was divided into two factors: *ocean stewardship and marine awareness,* with KMO and Bartlett's test values of 0.887 and 1436.708. The second factor was named *ocean awareness,* based on McKinley and Fletcher (2010) concepts, which includes the degree of importance placed on marine conservation, the level of engagement with ocean issues, and the willingness to contribute to the ocean's well-being based on one's own strengths. The skill dimension includes two factors: *education promotion and problem solving,* with KMO and Bartlett's test values of 0.926 and 1812.528, respectively. The resulting path diagram, generated by AMOS after the corrections, is depicted in Figure 1.

Marine Research of the National Academy of Marine Research
DOI: 10.29677/MR.202306_3(1).0001

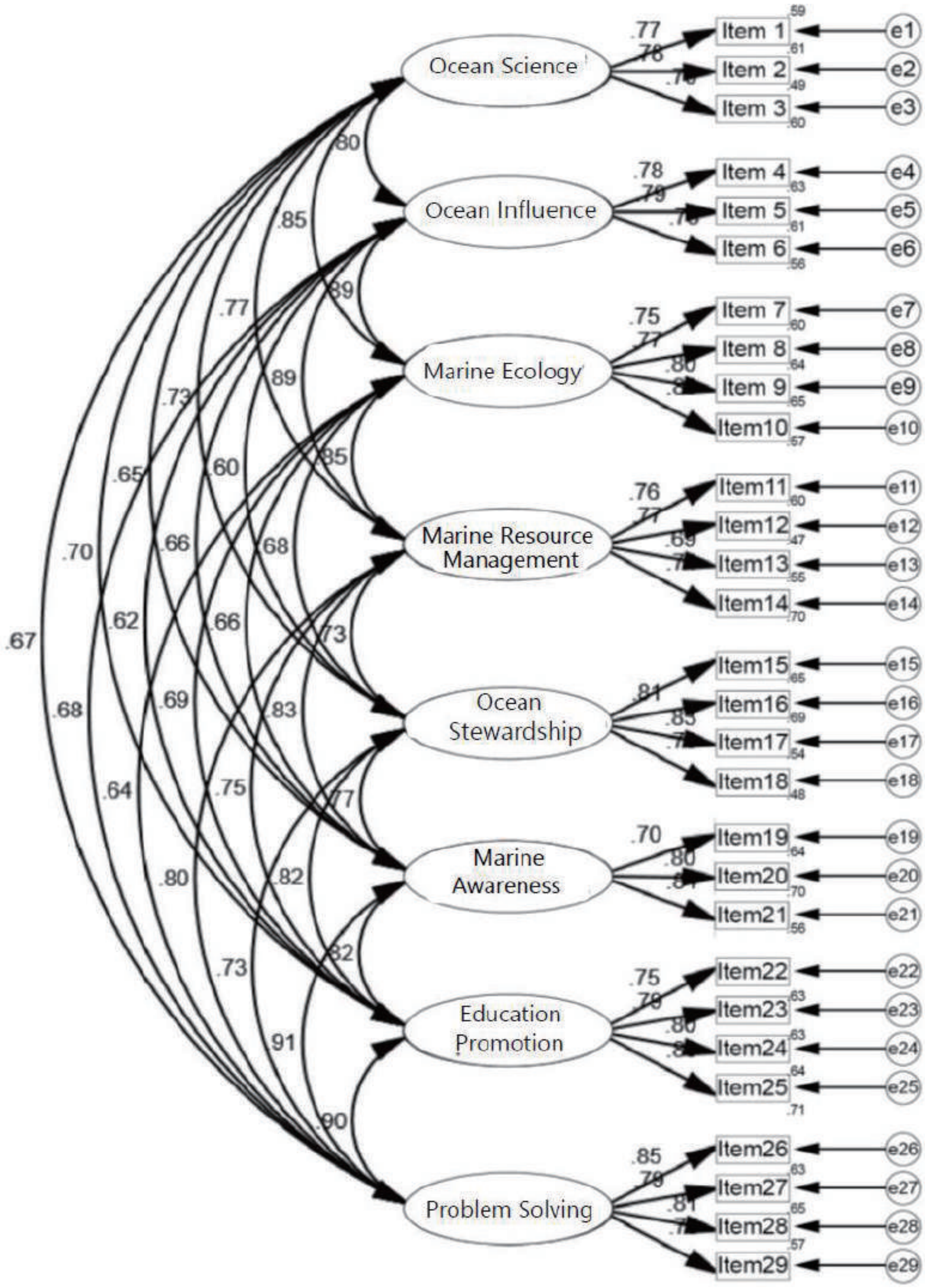

Figure 1. CFA model of marine science learning effectiveness.

4.3.3 Preliminary fit index after revision

The standard errors of the 29 items were between 0.05 and 0.07, and no excessive standard errors were observed. The factor loadings ranged from 0.68 to 0.84, all within the standard of 0.50–0.95. The error variance (e1-e29) was between 0.03 and 0.67, and no negative values were observed. Based on the previous exploratory factor analysis, the attitude dimension was split into two factors, and a second confirmatory factor analysis was conducted after the items were adjusted. The χ^2 value was 761.120 (p = .000), and the GFI and NFI were both >0.9 after correction. Although the RFI did not reach 0.9, it was within the acceptable range.

Marine Research of the National Academy of Marine Research
DOI: 10.29677/MR.202306_3(1).0001

Table 6. SEM Model fit.

Indicator		Verification Value	Fitness Index	Fitness Judgment
Absolute fit index	Chi-square/df	2.181	<3.0，P>0.05	Pass
	GFI	.943	>0.9	Pass
	RMR	.047	<0.08	Pass
	RMSEA	.056	<0.08	Pass
Value added fit index	AGFI	.848	>0.8 Acceptable	Acceptable
	NFI	.900	>0.90	Pass
	RFI	.884	>0.8 Acceptable	Acceptable
	CFI	.943	>0.90	Pass
	IFI	.944	>0.90	Pass
	PGFI	.704	>0.50	Pass
	PNFI	774	>0.50	Pass

4.3.4 Internal structural fit of the modified model

After the order of the items was corrected, the CRs of the eight potential variables were between 0.7 and 0.8, which exceeded the standard of 0.6 (Bagozzi et al., 1998), and the AVE was higher than the standard of 0.5, indicating that the 29 items can reflect the eight potential variables. This study also used R2 values to examine each observation variable's percentage that could be explained by the likely variable. The R2 value of each observation variable was between 0.41 and 0.71, which exceeded 0.25, indicating that the scale had suitable convergent validity.

4.4 Reliability analysis after revision

After the items were adjusted, the α coefficient and its 95% CI were estimated again. The overall reliability was 0.935, and the reliability of all three dimensions exceeded 0.80. The reliability of the five major factors, namely ocean influence, marine ecology, marine resource management, ocean stewardship, and marine awareness, exceeded 0.80 after item revision, indicating that the revised subscale has good reliability.

Table 7. Reliability analysis after revision.

Facet	Category	Number of Items	Factor Reliability	Total Reliability
Cognition	Ocean science	3	.794	.935
	Ocean influence	3	.825	
	Marine ecology	4	.860	
	Marine resource management	4	.830	
Attitude	Ocean stewardship	4	.877	.894
	Marine awareness	3	.818	
Skill	Education promotion	4	.864	.920
	Problem solving	4	.878	

4.5 Confidence interval after revision

The 95% CIs of the revised factors were estimated to test whether each factor's α coefficient differed significantly from 0.7 after item revision. The F test results were F (371,742) = 1.719 (p = .000) for ocean influence; F (371,1113) = 2.143 (p =.000) for marine ecology; F (371,1113) = 1.764 (p = .000) for marine resource management; F (371,1113) = 2.442 (p = .000) for the ocean stewardship; and F (371,742) = 1.646 (p = .000) for marine awareness. The p values of these five factors indicated that the test results were in the rejection zone; therefore, the null hypothesis of α = 0.70 was rejected, and the 95% CI of the five factors indicated that α was significantly greater than 0.70, indicating good reliability.

4.6 Summary

The questionnaire was distributed at the end of Science for All Week to a sample of 372 students from third to sixth grade. AMOS software was used to analyze the data and understand the relationships between factors, questions, and error variables. The scale showed good fit indicators and factor loadings within the acceptable range. No excessive standard errors or negative error variation values were observed. The preliminary adaptation index indicated a satisfactory fit. However, the AVEs for marine ecology, marine resource management, and problem solving did not meet the required standard and needed revision. Exploratory factor analysis was conducted to confirm the factors that could be measured using the scale. Question 7 was reclassified under marine ecology, and question 11 was reclassified under marine resource management. The analysis also revealed the division of ocean stewardship into ocean stewardship and marine awareness, with common factors identified in questions 19, 20, and 21. The marine science learning scale was ultimately divided into eight categories and 29 questions, encompassing cognitive variables, attitude variables, and skills variables related to ocean science, ocean influence, marine ecology, marine resource management, ocean stewardship, marine awareness, education promotion, and problem solving.

Table 8. Revised scale.

Facet	Factors	N	Questions
Cognition	Ocean science	1	I understand why the temperature and wind can cause currents.
		2	I understand why there are variations in seawater salinity and pressure.
		3	I understand that seawater is continuously circulating.
	Ocean influence	4	I understand that the ocean has a massive impact on climate change.
		5	I understand that the ocean provides oxygen and absorbs carbon dioxide.
		6	I understand that the ocean significantly impacts the lives of most people.
	Marine ecology	7	I understand marine habitats can support the survival of marine organisms.
		8	I understand the food web of marine life.
		9	I understand the relationship between marine life and the environment.
		10	I understand that the marine ecosystem has diverse environments.
	Marine resource management	11	I understand that certain marine animals require legal protection.
		12	I understand the importance of marine protected areas for marine life.
		13	I understand the impact of marine debris on the environment.
		14	I understand that some marine resources require a long time to regenerate.
Attitude	Ocean stewardship	15	I will actively learn marine science knowledge.
		16	I am willing to try to learn new things about the ocean.
		17	I am very interested in understanding ocean science.
		18	I will donate money or other resources to support the marine environment.
	Marine awareness	19	Marine environmental conservation is a very important thing for me.
		20	I will take the initiative to care and understand the state of the ocean.
		21	I am willing to give my own strength to protect the marine environment.
Skill	Education promotion	22	I can lead others to discuss ocean issues.
		23	I can share ocean problems to others which reflect on myself.
		24	I can collect and integrate information about the ocean.
		25	I can share ocean science knowledge with others.
	Problem solving	26	I can identify issues in the ocean and propose solutions to address them.
		27	I can apply the knowledge and skills I have learned in daily life.
		28	I can find appropriate solutions to address the problems I meet.
		29	I can communicate with others to collectively find solutions to ocean problems.

DOI: 10.29677/MR.202306_3(1).0001

5 CONCLUSIONS

5.1 Conclusions

This study utilized exploratory factor analysis and confirmatory factor analysis to examine the reliability and validity of a marine science learning effectiveness scale. The scale was categorized into cognition, attitude, and skills to address the educational goals. It fills the gap in measuring attitudes and skills related to ocean literacy. The cognitive dimension included ocean science, ocean influence, marine ecology, and marine resource management. The attitude dimension comprised ocean stewardship and marine awareness, while the skills dimension consisted of education promotion and problem solving. The revised fitness indices of the scale's model, such as χ^2/df, GFI, AGFI, NFI, RFI, CFI, RMR, and RMSEA, were acceptable. The standardized factor loadings were significant, and the AVE values demonstrated satisfactory convergent validity. The subscales and overall scale exhibited good reliability with CR values exceeding the threshold of 0.70. Thus, the subscales and scale are highly reliable for marine science activities.

Among the 287 extracted concepts, learning effectiveness, ocean science, and active learning constituted a significant portion. These concepts align with the goals of science education to enhance students' opportunities for learning and their scientific knowledge through experiential activities. They also aim to develop presentation skills, increase students' sense of achievement, enhance teachers' professional knowledge in marine science, and promote science education. In this study, cognitive concepts represented over one-third of all extracted concepts, indicating the importance of transmitting marine scientific knowledge in marine science activities. After consultation with experts and scholars, the 103 concepts were further categorized into marine scientific knowledge, marine ecology, ocean influence, and marine resource management. These concepts closely corresponded to the marine science concepts proposed by Lambert (2005), suggesting that the cognitive dimension adequately covers content knowledge.

This study utilized a Grounded Theory approach to synthesize the perspectives of curriculum designers and participants in marine science activities. It also organized teaching materials such as lesson plans and worksheets and developed a scale to measure the effectiveness of marine science learning. The scale encompasses three main dimensions: cognition, attitude, and skills, with eight major constructs: ocean science, ocean influence, marine ecology, marine resource management, ocean stewardship, marine awareness, education promotion, and problem solving. The scale was designed based on previous research, the United Nations Decade of Ocean Science for Sustainable Development, and the concepts of ocean literacy scope and sequence in grades 3-5. Through long-term accumulation of academic research on the effectiveness of marine science learning, it is hoped that this scale can contribute to the promotion of global ocean literacy education and the achievement of the United Nations' goals for sustainable development of the oceans.

5.2 Application

The integration of the curriculum alone may not comprehensively promote marine education and may be limited to enhancing cognitive levels. Currently, the scales presented in relevant research also predominantly focus on cognitive levels. Therefore, the main focus of this study is to construct a scale consisting of three major categories: cognition, attitude, and skills, comprising eight dimensions and 29 items. The study aims to provide an assessment tool primarily for marine science activities, enabling the evaluation of short-term learning outcomes in marine science activities. In terms of attitudes and skills, the dimensions include ocean stewardship, marine awareness, education promotion, and problem solving. This assessment scale can be applied to most marine science learning activities, and it is hoped that it can serve as a reference for future marine science activities.

DOI: 10.29677/MR.202306_3(1).0001

5.3 Research limitations

This study focused on utilizing the National Science Week activities of the NMMST as a sample to construct the scale. The activities were designed with specific themes, such as crab harvest, buoyancy, beach clean-up, coral reef, and underwater gliders, for elementary school students. The extracted concepts primarily reflected the knowledge conveyed through these activities. It is important to note that the knowledge covered in these activities may not encompass the entire scope of marine science.

5.4 Research suggestions

Marine science encompasses diverse disciplines and knowledge, making it important to consider multiple fields when constructing scales. The ocean literacy framework provides a comprehensive model for promoting ocean science. However, it is crucial to also incorporate human emotions in future research to enhance the understanding of marine education outcomes. The scale developed in this study focused on the cognitive abilities of third to sixth graders, but researchers can adapt and expand it for different age groups to gather more teaching results in marine education. The scale exhibited excellent reliability, with an overall reliability exceeding 0.90 and subscale reliabilities reaching 0.80. Researchers can use individual subscales to measure learning effectiveness based on specific educational objectives. The scale enables the assessment of students' cognition, attitude, and skills in marine science activities and provides a comprehensive understanding of their learning effectiveness; thus, the scale has versatile applications. Given the gradual degradation of the ocean and the human impact on its destruction, education plays a vital role in transmitting marine knowledge through various educational methods. The developed scale has universal applicability for promoting marine education, disseminating ocean science, and advancing marine science education efforts.

ACKNOWLEDGEMENTS

This study acknowledges the financial support from the National Science Council (NSC-109-2410-H-019-009) and the contributions of all the experts and students who assisted in conducting this study. We would also like to express our gratitude to the National Taiwan Ocean University for its administrative support and the members of the NTOU RAYS Family for their assistance in executing this project.

REFERENCES

Awan, A. G. (2013). Relationship between environment and sustainable economic development: A theoretical approach to environmental problems. *International Journal of Asian Social Science, 3*(3), 741-761. https://archive.aessweb.com/index.php/5007/article/view/2451

Bagozzi, R. P., Yi, Y., & Nassen, K. D. (1998). Representation of measurement error in marketing variables: Review of approaches and extension to three-facet designs. *Journal of Econometrics, 89*(1-2), 393-421. https://doi.org/10.1016/S0304-4076(98)00068-2

Borja, A., Santoro, F., Scowcroft, G., Fletcher, S., & Strosser, P. (2020). Connecting People to Their Oceans: Issues and Options for Effective Ocean Literacy. *Frontiers in Marine Science, 6,* 837. https://doi.org/10.3389/fmars.2019.00837

Boston, M. D., & Candela, A. G. (2018). The instructional quality assessment as a tool for reflecting on instructional practice. *ZDM, 50,* 427-444. https://doi.org/10.1007/s11858-018-0916-6

Brennan, C., Ashley, M., & Molloy, O. (2019). A system dynamics approach to increasing ocean literacy. *Frontiers in Marine Science, 6*. https://doi.org/10.3389/fmars.2019.00360

Chang, C. C. (2019). Development of Ocean Literacy Inventory for 16- to 18-Year-Old Students. *SAGE Open, 9*(2). https://doi.org/10.1177/2158244019844085

Chauhan, S. (2017). A meta-analysis of the impact of technology on learning effectiveness of elementary students. *Computers & Education, 105*, 14-30. https://doi.org/10.1016/j.compedu.2016.11.005

Cheng, S. C., She, H. C., & Huang, L. Y. (2017). The impact of problem-solving instruction on middle school students' physical science learning: Interplays of knowledge, reasoning, and problem-solving. Eurasia *Journal of Mathematics, Science and Technology Education, 14*(3), 731-743. https://doi.org/10.12973/ejmste/80902

Chou, C. M., Shen, C. H., Hsiao, H. C., & Shen, T. C. (2019). An Investigate of Influence Factor for Tertiary Students' M-Learning Effectiveness: Adjust Industry 4.0 & 12-Year Curriculum of Basic Education. *International Journal of Psychology and Educational Studies, 6*(2), 66-76. http://dx.doi.org/10.17220/ijpes.2019.02.007

Dewey, J. (1986). Experience and education. *The Educational Forum, 50*(3), 241-252. https://doi.org/10.1080/00131728609335764

Doussis, E. (2017). Marine Scientific Research: Taking Stock and Looking Ahead. In G. Andreone (Eds), *The Future of the Law of the Sea* (pp. 87-103). Springer, Cham. https://doi.org/10.1007/978-3-319-51274-7_5

Dupont, S., and Fauville, G. (2017). Ocean literacy as a key to sustainable development and ocean governance. In P. A. L. D. Nunes, L. E. Svensson, & A. Markandya (Eds.), *Handbook on the Economics and Management of Sustainable Oceans* (26, pp. 519-537). Edward Elgar Publishing.

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

Fornell, C., & Larcker, D. F. (1981). Structural equation models with unobservable variables and measurement error. Algebra and statistics. *Journal of Marketing Research, 18*(3), 382-388. https://doi.org/10.2307/3150980

Gough, A. (2017). Educating for the marine environment: Challenges for schools and scientists. *Marine Pollution Bulletin, 124*(2): 633-638. https://doi.org/10.1016/j.marpolbul.2017.06.069

Guan, S., Qu, F., & Qiao, F. (2023). United Nations Decade of Ocean Science for Sustainable Development (2021-2030): From innovation of ocean science to science-based ocean governance. *Frontiers in Marine Science, 9*. https://doi.org/10.3389/fmars.2022.1091598

Heimlich, J. E., Mony, P. & Yocco, V. (2012). Belief to Behavior: A Vital Link. *International Handbook of Research on Environmental Education* (pp. 262-274). Routledge. https://doi.org/10.4324/9780203813331

Hilmi, N., Theux-Lowen, N., & Crisóstomo, M. B. (2022). Ocean-Related Impacts of Climate Change on Economy. In Leal Filho, W., Azul, A. M., Brandli, L., Lange Salvia, A., Wall, T. (Eds.), *Life Below Water*. Springer, Cham. https://doi.org/10.1007/978-3-319-71064-8_158-2

Lam, J. (2018). The Pedagogy-Driven, Learner-Centered, Objective-Oriented and Technology-Enable (Plot) Online Learning Model. *PUPIL: International Journal of Teaching, Education and Learning, 2*(2): 66-80. https://doi.org/10.20319/pijtel.2018.22.6680

Lambert, J. (2005). Students' Conceptual Understandings of Science After Participating in a High School Marine Science Course. *Journal of Geoscience Education, 53*(5): 531-539. https://doi.org/10.5408/1089-9995-53.5.531

Lambert, J. (2006). High School Marine Science and Scientific Literacy: The promise of an integrated science course. *International Journal of Science Education, 28*(6), 633-654. https://doi.org/10.1080/09500690500339795

Lin, Y. L., Huang, S. W., & Chang, C. C. (2019). The Impacts of a Marine Science Board Game on Motivation, Interest, and Achievement in Marine Science Learning. *Journal of Baltic Science Education, 18*(6), 907-923. https://doi.org/10.33225/jbse/19.18.907

Lin, Y. L., Wu, L. Y., Tsai, L. T., & Chang, C. C. (2020). The Beginning of Marine Sustainability: Preliminary Results of Measuring Students' Marine Knowledge and Ocean Literacy. *Sustainability, 12*(17), 7115. https://doi.org/10.3390/su12177115

Markos, A., Boubonari, T., Mogias, A., & Kevrekidis, T. (2015). 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

McKinley, E., & Fletcher, S. (2010). Individual responsibility for the oceans? An evaluation of marine citizenship by UK marine practitioners. *Ocean & Coastal Management, 53*(7), 379-384. https://doi.org/10.1016/j.ocecoaman.2010.04.012

McKinley, E., Burdon, D., & Shellock, R. J. (2023). The evolution of ocean literacy: A new framework for the United Nations Ocean Decade and beyond. *Marine Pollution Bulletin, 186,* 114467. https://doi.org/10.1016/j.marpolbul.2022.114467

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,* 396. https://doi.org/10.3389/fmars.2019.00396

Mokos, M., Realdon, G., & Zubak Čižmek, I. (2020). How to Increase Ocean Literacy for Future Ocean Sustainability? The Influence of Non-Formal Marine Science Education. *Sustainability, 12*(24), 10647. https://doi.org/10.3390/su122410647

Ostroff, W. L. (2016). *Cultivating curiosity in K-12 classrooms: How to promote and sustain deep learning.* ASCD.

Salpin, C., Onwuasoanya, V., Bourrel, M., & Swaddling, A. (2018). Marine scientific research in pacific small island developing states. *Marine Policy, 95*, 363-371. https://doi.org/10.1016/j.marpol.2016.07.019

Santoro, F., Santin, S., Scowcroft, G., Fauville, G., & Tuddenham, P. (2018). *Ocean literacy for all: a toolkit.* UNESCO, France.

Schoedinger, S., Cava, F., & Jewell, B. (2006). The Need for Ocean Literacy in the Classroom: part II. *Science Teacher, 73*(6), 48-53.

Schoedinger, S., Tran, L., & Whitley, L. (2010). *From the principles to the scope and sequence: a brief history of the ocean literacy campaign.* NMEA Special Rep, 3, 3-7.

Shernoff, D. J., & Csikszentmihalyi, M. (2009). Flow in schools: Cultivating engaged learners and optimal learning environments. In R. Gilman, E. S. Huebner, & M. Furlong (Eds.), *Handbook of positive psychology in schools* (1st ed., pp. 131-145). Routledge.

Tsai, L. T., & Chang, C. C. (2019). Measuring ocean literacy of high school students: Psychometric properties of a Chinese version of the ocean literacy scale. *Environmental Education Research, 25*(2), 264-279. https://doi.org/10.1080/13504622.2018.1542487

Tsai, L. T., Lin, Y. L., & Chang, C. C. (2019). An Assessment of Factors Related to Ocean Literacy Based on Gender-Invariance Measurement. *International Journal of Environmental Research and Public Health, 16*(19), 3672. https://doi.org/10.3390/ijerph16193672

United Nations (2012). *The future we want: draft resolution/ submitted by the President of the General Assembly.* UN. General Assembly (66th sess.: 2011-2012). https://digitallibrary.un.org/record/731519

Valdés, L. (2017). *Global ocean science report: the current status of ocean science around the world.* Intergovernmental Oceanographic Commission, UNESCO.

Vidergor, H. E. (2018). Effectiveness of the multidimensional curriculum model in developing higher-order thinking skills in elementary and secondary students. *The Curriculum Journal, 29*(1), 95-115. http://dx.doi.org/10.1080/09585176.2017.1318771

Warwick, P., Linfield, R. S., & Stephenson, P. (1999). A comparison of primary school pupils' ability to express procedural understanding in science through speech and writing. *International Journal of Science Education, 21*(8), 823-838. https://doi.org/10.1080/095006999290318

Winks, L., Ward, M., Zilch, J., & Woodley, E. (2020). Residential marine field-course impacts on ocean literacy. *Environmental Education Research, 26*(7), 969-988. https://doi.org/10.1080/13504622.2020.1758631

Yen, C.D. (Ray), & Sembiring, J. V. (2020). The Research of Experiential Learning to Enhance Ocean Stewardship and Pro-Environmental Behavior Intention-Cross-Cultural Comparison from Taiwan and Indonesia. *Creative Education, 11*(7), 1008-1025. https://doi.org/10.4236/ce.2020.117073

Zhang, L., Yuan, J., & Kim, C. (2023). Spatially Structured Environmental Analysis of Marine Ecological Landscapes Based on Machine Vision. *Journal of Marine Science and Engineering, 11*(5), 954. https://doi.org/10.3390/jmse11050954

DOI: 10.29677/MR.202306_3(1).0001