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Ocean literacy among Taiwanese and Japanese high school students

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ABSTRACT

The sea surrounds both Taiwan and Japan, but they have adopted different marine education policies. This study used the ocean literacy framework published by the National Oceanic and Atmospheric Administration to examine the ocean literacy of high school students in Taiwan and Japan. We also investigated the channels through which students acquired marine biology knowledge and whether parental education level and students' attitudes toward the ocean affected ocean literacy. Tests were administered in Japanese and Chinese to assess students' ocean literacy, attitude, and background. This study used descriptive statistics, the independent sample t-test, and multigroup structural equation modeling. Taiwanese students considerably outperformed Japanese students in ocean literacy, scoring significantly higher in five of the seven ocean literacy principles. In Taiwan, higher parental education level led to higher ocean literacy scores, but not in Japan. Access to information regarding marine biology also differed by country. These results provide a reference to high schools, teachers, and policymakers in Taiwan and Japan and can help improve curricula, learning environments, and marine education policies.

1. Introduction

This study used the English and Chinese versions of the International Ocean Literacy Survey (IOLS), developed by Tsai and Chang [1] and Fauville et al. [2] to explore ocean literacy (OL) among high school students in Taiwan and Japan and to understand the effects of parental education level (P.EDU) and students' attitude (ATT) toward the ocean on OL. Taiwan and Japan have adopted different approaches to marine education. Japanese marine education is promoted through social education. Sasaki [3] mentioned that marine education should be integrated into teaching materials to help students understand marine sciences, develop respect for the ocean, and create a society with extensive ocean knowledge. A total of 12 concepts should be incorporated into the teaching and supplementary materials for students of all ages. After the 2011 Tohoku earthquake and tsunami, the Japanese government was urged to increase its investment in marine education, promote it through official and unofficial channels, and follow the US model [4]. However, in Taiwan, marine education has been incorporated into various courses and focuses on OL's relationship with recreation, culture, society, science, technology, resources, and sustainability. Because of these differences in the educational system, OL among Taiwanese and Japanese students should be explored.

1.1. Marine education in Taiwan and Japan

Both Taiwan and Japan are surrounded by and dependent on the ocean, but their policies on marine education are different. One study analyzed Japanese elementary and high school textbooks and revealed that topics related to rivers, oceans, and water constituted 21.7 % of the content of elementary school textbooks and 34.5 % of high school textbook content [5]. These percentages are considerably higher than those in Taiwanese textbooks (< 10 %)[6], indicating an emphasis on these topics in Japan. However, Sasaki [3] suggested that the amount of marine education content in Japanese elementary and high school textbooks was insufficient to provide students with a systematic understanding of the ocean. The White Paper on Oceans and Ocean Policy published by Japan's Ocean Policy Research Institute in 2004 indicated that the core elements of marine education are the ability to protect the ocean, knowledge of the ocean, and proper use of the ocean. To instill these core elements in students and promote marine education nationwide, the institute published the Basic Act on Ocean Policy in 2007, the first comprehensive marine policy in Japan, defining the key goals.

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Article 28 of the act states that marine education in Japan should deepen the nation's understanding of and care for the ocean through school and social education, signing treaties regarding the ocean and the use of its resources, and implementing sustainable practices. It also proposes measures such as allocating government resources to interdisciplinary education, university research on marine science, and training professionals in marine science. The act drives policies that reflect the ocean's critical role in Japan and promote marine education [5]. The Ocean Policy Research Institute of Japan publishes elementary, middle, high school, and vocational high school marine education guidelines [4]. The guidelines provide supplementary lesson plans for teachers of each grade to ensure marine education. They also provide recommended lessons on caring for the ocean, human–ocean interaction, marine resources, and understanding and connecting with the ocean [4].

Taiwan performs better in promoting marine education than Japan, the U.S., and European countries mainly in the following four ways: (1) Taiwan has established the Curriculum Guidelines of Marine Education Issues, formulated by the Ministry of Education, which extends the Competence Indicators of Ocean Education for nine-year integrated education to the substantive content of marine education issue for 12-year compulsory education; (2) Taiwan has a policy to educate students on marine issues before high school; (3) Commissioned by the Ministry of Education, the Taiwan Marine Education Center conducts a comprehensive marine literacy test for students of the sixth, ninth, and twelfth grades nationwide, which is one of the largest tests of its kind among countries in the world. The results of the test are used as a reference for the revision of the national marine education policy and the marine education implementation of counties and cities; (4) Taiwan's marine education takes into account both humanities and the natural aspects. Taiwan promotes the five cores of learning simultaneously, including marine leisure, society, culture, science and technology, and resources and sustainability [6], while the Curriculum Guidelines of Marine Education of Taiwan is its biggest advantage.

Taiwan's marine education is implemented with the integration of major issues, and is carried out in accordance with the goal of developing marine education. The *White Paper on Marine Education Policy* was published in 2007, to outline the foundation of Taiwan's blueprint for marine education. Based on this, the Curriculum Guidelines of Marine Education Issues for Primary and Secondary Schools were issued in 2008 to include marine education issues into the Nine-Year Integrated Curriculum, as well as senior high school and vocational high school subjects. In contrast to following the international definition of marine literacy that focuses on marine science, the new guidelines emphasize the appropriate interaction between people and the ocean, creating an educational environment that encourages being close to, loving, and understanding the sea. The daily life of human beings is closely related to the ocean. However, due to political and cultural factors in Taiwan's early days, its marine education developed at a slower pace compared with other countries. Moreover, most of the serving teachers had no training in marine education. Students could only obtain ocean-related information through other means (such as family education, cultures and customs, or life experience), which led them to receive wrong concepts or myths, and these factors hindered students' learning of ocean education [7]. Therefore, Taiwan's education authorities realized the importance of marine education and constructed a complete and feasible strategy to implement marine education.

1.2. *Definition of ocean literacy*

Because people's lives are closely related to the sea, understanding and improving the ocean literacy of students and the general public are particularly crucial. Ocean literacy leads to informed participation in the discussion on the future of the oceans and responsible and effective decision making [2]. Ocean literacy requires individuals to be empowered with knowledge and inspired to act [8]. These acts can involve communicating about the ocean in a meaningful way as well as making informed decisions about behavior changes at individual as well as societal scales. Additionally, a person with ocean literacy understands the origin and basic concepts of the ocean and can convey marine knowledge and form clear and meaningful conclusions regarding the ocean and its resources [9]. Based on marine science, the NMEA (National Marine Educator Association) defines ocean literacy as "an understanding of the ocean's influence on you, and your influence on the ocean" [10]. According to this definition, the NMEA developed a framework regarding ocean literacy, namely The Essential Principles of Ocean Science K-12 (Ocean Literacy Principles) and the Ocean Literacy Scope and Sequence for Grades K-12 (Scope and Sequence). The seven principles of ocean literacy are (P1) Earth has one large ocean with many features, (P2) The ocean and life in the ocean shape the features of Earth, (P3) The ocean is a significant influence on weather and climate, (P4) The ocean made Earth habitable, (P5) The ocean supports a great diversity of life and ecosystems, (P6) The ocean and humans are inextricably interconnected, and (P7) The ocean is largely unexplored [10]. The Ocean Literacy Principles and Scope and Sequence also provide formal and informal educators and curriculum and project designers with a framework diagram for establishing coherent and sound marine learning content for kindergarten to 12th grade (K-12) students.

1.3. *Ocean literacy survey*

There are some OL investigations performed in Taiwan but not in Japan [7,11–14]. These surveys have also revealed low OL and little knowledge of marine science among Taiwanese students [7,11–14]. Chang [11] investigated middle school students' knowledge of marine science, OL, and marine science skills; the students answered 50 % of questions on marine science correctly. This indicates insufficient knowledge of marine science and misconceptions about the ocean. Lwo et al. [7] reported that high school students had an average accuracy of 50 % in identifying misconceptions about the ocean, with accuracy lower than 50 % for more than half of the assessment items. This indicates that these students' educational materials about the ocean were insufficient in elementary and high school. Chang et al. [12] indicated that vocational high school students exhibited unsatisfactory OL, with an average accuracy lower than 50 % on the OL assessment. They also had only a basic understanding of the ocean. The middle school students exhibited an accuracy rate of 63 % for ocean literacy sentence-making, indicating a basic performance level [13]. Tsai [14] collected 1944 high school students in Taiwan to understand their performance in OL. The research results also showed that the response rate of high school students on the ocean literacy questionnaire was about 60 %.

1.4. *Influence of variables on the ocean literacy*

The present study examined how Taiwan and Japan's marine education policies have affected the OL of high school students. Numerous studies have reported that students' OL can differ considerably by country. In addition, this study explored how P.EDU and ATT affect OL. Scholars have also examined differences in OL between male and female students [7,11,15]; Chang [11] observed no significant differences, but Lwo et al. [7] discovered that female high school students scored significantly higher on marine science tests than male students. Moreover, men were reported to significantly outperform women in self-assessed knowledge of marine biology and on tests [15]. Some studies have indicated that women are more concerned about problems affecting the ocean than men [16,17].

Studies [18,19] have demonstrated that socioeconomic factors (e.g., parental education level and income) affect students' literacy and performance in science. Scholars have also noted the particular importance of the relationship between parental education and student performance in science [18,20,21]. Kalender and Berberoglu [18] used parental education as a socioeconomic status indicator and noted that it affected students' science performance. Caldas and Bankston [22] also used parental education as a proxy for family socioeconomic status and revealed that it considerably affected students' performance in science. Although marine education is a crucial component of science curricula, few studies have explored how P.EDU affect students' OL.

Academic performance is also affected by ATT. Positive ATT and strong motivation help students learn and achieve higher academic performance. Students' ATT toward the environment also affects their marine education [23,24]; however, few studies have explored this relationship. Greely [23] indicated that knowledge of the ocean and ATT toward the environment contribute substantially to OL. Fortner and Mayer [24] revealed that ATT toward the ocean and the Great Lakes determined individuals' knowledge of them.

Studies have explored the OL of Japanese and Taiwanese students separately using different frameworks, which has precluded the comparison of the two groups. The present study employed the OL framework of the National Oceanic and Atmospheric Administration (NOAA). We investigated the channels through which students acquired knowledge of the ocean and whether P.EDU and students' ATT affect their OL. The results could help high schools in Taiwan and Japan understand the factors that affect students' OL and improve their curricula and learning environment.

2. Methods

2.1. Materials and procedure

Students' OL, ATT, and background (gender, P.EDU, and source of knowledge) were evaluated. The IOLS, developed for students aged 16–18 years and originally in English, was used to assess the OL. Because of enthusiasm in the OL community, volunteer researchers have translated it into 16 languages [2]. Tsai and Chang [1] and Fauville et al. [2] indicated that the IOLS has satisfactory psychometric properties (e.g., reliability and validity). It comprises seven principles that constitute OL; the principles have 48 items in total, with 38 being single-choice items and 10 being multiple-choice. Table 1 presents the items for each principle. P2, P4, and P7 have fewer items, which is consistent with the SOLE (survey of ocean literacy and experience) developed by Markos et al. [25]; the items in these principles are difficult to answer correctly, and measuring students' knowledge of the ocean through paper-and-pencil tests is challenging [1]. For more details, refer to Tsai and Chang [1] and Fauville et al. [2].

Students' ATT was mainly assessed using items based on those developed by Tsai et al. [26] Three items were used ("I enjoy learning about the ocean," "Marine biology is boring," and "I like marine biology" [26]). Each item was rated on a 4-point Likert-type scale (1 = *strongly disagree*, 2 = *slightly disagree*, 3 = *slightly agree*, and 4 = *strongly agree*). The second item was reverse scored. Higher scores indicated more positive ATT toward the ocean. The method suggested by Tsai et al. [26] and Tsai et al. [27], which was based on a 4-point Likert-type scale (1 = middle school or below, 2 = high school, 3 = university, 4 = master's degree or above) was used to measure P.EDU.

Table 1
Number of items in the scale that feature the seven principles of ocean literacy.

Essential principle	No. of items
P1: The Earth has one big ocean with many features (Features of the ocean)	15
P2: The ocean and life in the ocean shape the features of Earth (The ocean and its life shape earth)	3
P3: The ocean is a major influence on weather and climate (Weather and climate)	10
P4: The ocean made Earth habitable (The ocean made earth habitable)	3
P5: The ocean supports a great diversity of life and ecosystems(The diversity of life and ecosystems)	9
P6: The ocean and humans are inextricably interconnected (The ocean and humans are interconnected)	6
P7: The ocean is largely unexplored (The ocean is largely unexplored)	2
Total	48

The Chinese and Japanese questionnaire versions were used in Taiwan and Japan, respectively. Because this study was conducted between May 2020 and March 2021, during the COVID-19 epidemic, data were collected online through a web survey. The respondents were from the northern, central, and southern parts of Taiwan, northeastern Japan, and the Tokyo area. Teachers helped the students complete the survey during class on a computer. Some schools were closed due to the pandemic and could not administer the questionnaires, which is a limitation of this study.

2.2. Participants

A total of 750 and 542 high school students from Taiwan and Japan, respectively, completed the questionnaire. A total of 69 and 46 incomplete questionnaires were excluded, leaving 681 and 493 valid questionnaires from Taiwan and Japan, respectively; 351 (51.5 %) of the Taiwanese students were male and 330 (48.5 %) female, whereas 255 (51.7 %) of the Japanese students were male and 238 (48.3 %) female.

2.3. Statistical analysis

This study used descriptive statistics, the independent sample t-test, and an evaluation of measurement invariance across countries. Measurement invariance was tested hierarchically through a series of seven nested models with successive equivalence constraints across groups [28]. Measurement invariance was determined by assessing the change in the root mean square error of approximation (RMSEA); a change of $>$ 0.07 indicated no measurement invariance [26,29]. Multigroup structural equation modeling (MG-SEM) was used to determine whether the relationships among the hypothesized model's latent variables fit the data. Several criteria and cutoffs were used to assess the confirmatory factor analysis model [28,30]. A comparative fit index (CFI) of > 0.97 indicates a satisfactory model–data fit, whereas 0.90 is acceptable for the lower bound [31]. An RMSEA < 0.05 indicates adequate fit, $0.05 <$ RMSEA < 0.08 suggests moderate fit, and RMSEA > 0.10 indicates poor fit [30,32]. Standardized root mean squared residual (SRMR) > 0.05 also indicates adequate model–data fit [30]. The MG-SEM parameters were estimated using Mplus [33] based on maximum likelihood estimation.

3. Results

3.1. Sources of knowledge

Fig. 1 presents the analysis results of sources of knowledge and information. The three most common sources for Taiwanese students were museums, TV, and classes (67.1 %, 62.0 %, and 51.2 %, respectively). For Japanese students, the most common sources were school-based promotional activities (i.e., marine accident and disaster prevention promotion), TV, and classes (62.9 %, 53.5 %, and 49.7 %, respectively).

3.2. Mean comparison

Fig. 2 presents the results for each principle of the OL scale. The Taiwanese and Japanese students answered more than 50 % of the questions correctly; 61.3 % for the Taiwanese students and 51.2 % for the Japanese students. Both groups answered the most questions correctly for P1 and P3, but the Taiwanese students answered more questions correctly in five of the seven principles (P1–P3, P5, and P6) than the Japanese students.

The total scores and scores for each principle were averaged. Table 2 presents the means and standard deviations. An absolute value of 3 was

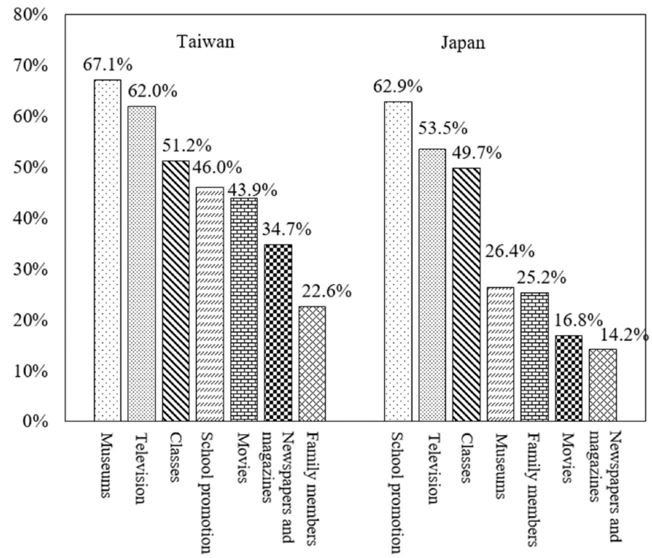

Fig. 1. Sources of marine knowledge for students.

used as the threshold for skewness and kurtosis to determine normal data distribution [34,35]. In Taiwan, the skewness and kurtosis for the variables were from − 1.381 to 0.495 and from − 0.769 to 2.159, respectively. In Japan, the skewness and kurtosis for the variables were from − 0.493 to 0.432 and from − 1.237 to 0.174, respectively. The values were within the acceptable range. The independent sample t-test was conducted to compare the average scores between genders and countries, with the total scores and scores for each principle as the dependent variables; Table 2 presents the results. Significant differences in the total score and the score for each principle were observed between the Taiwanese and Japanese students. For P1–P3, P5, P6, and total scores, the Taiwanese students (M = 10.8, 1.78, 6.9, 4.76, 3.22, and 29.43, respectively) had significantly higher scores than the Japanese students (M = 8.97, 1.36, 5.21, 4.05, 2.67, and 24.52, respectively). For P4 and P7, the Taiwanese students (M = 1.18 and 0.8, respectively) had significantly lower scores than the Japanese students (M = 1.32 and 0.99, respectively).

Among the Taiwanese students, the female students had significantly higher scores for six of the eight dependent variables than the male students (all but P5 and P7). The average P1–P4, P6, and total scores for the female students were 10.99, 1.92, 7.28, 1.26, 3.44, and 30.5, respectively, while those for the male students were 10.62, 1.64, 6.53, 1.10, 3.01, and 28.43, respectively. The female students in Taiwan outperformed the male students, whereas the male students in Japan significantly outperformed the female students. Among the Japanese students, the male students had significantly higher scores than the female students for seven of the eight dependent variables (all but P3). The average P1, P2, P4, P5, P7, and total scores for the male students were 9.27, 1.43, 1.49, 4.2, 2.76, 1.06, and 25.52, respectively, whereas those for the female students were 8.62, 1.29, 1.16, 3.89, 2.57, 0.92, and

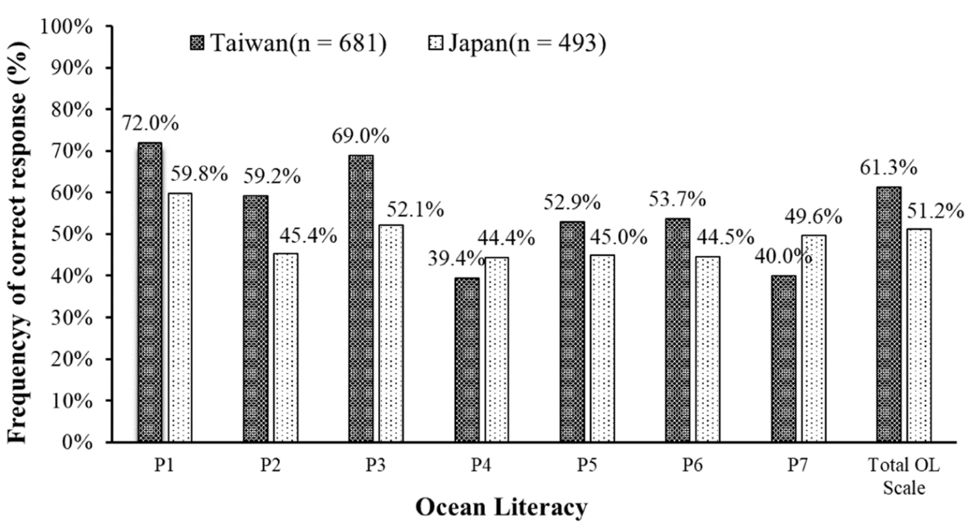

Fig. 2. Relative frequencies of correct answers per principle and total OL scale. *Note.* P1:The Earth has one big ocean with many features; P2:The ocean and life in the ocean shape the features of Earth; P3:The ocean is a major influence on weather and climate; P4:The ocean made Earth habitable; P5:The ocean supports a great diversity of life and ecosystems; P6:The ocean and humans are interconnected; P7:The ocean is largely unexplored.

Table 2
Descriptive statistics for OL and other variables.

Item/observed variable	Taiwan			Japan			Total sample		
	Male (n = 351) Mean (SD)	Female (n = 330) Mean (SD)	t	Male (n = 255) Mean (SD)	Female (n = 238) Mean (SD)	t	Taiwan (n = 681) Mean (SD)	Japan (n = 493) Mean (SD)	t
P1: Features of ocean	10.62(2.65)	10.99(1.97)	-2.07*	9.27(2.09)	8.62(2.13)	3.83**	10.80(2.36)	8.97(2.13)	13.67***
P2: Ocean & its life shape Earth	1.64(0.71)	1.92(0.59)	-5.66***	1.43(0.72)	1.29(0.65)	2.30*	1.78(0.66)	1.36(0.69)	10.51***
P3: Weather and climate	6.53(2.43)	7.28(1.85)	-4.49***	5.31(1.76)	5.11(1.81)	1.22	6.90(2.20)	5.21(1.78)	13.98***
P4: Earth habitable	1.10(0.66)	1.26(0.67)	-2.97**	1.49(0.72)	1.16(0.63)	5.47***	1.18(0.67)	1.32(0.69)	-3.73***
P5: Diversity of life and ecosystems	4.70(1.91)	4.82(1.63)	-0.85	4.20(1.41)	3.89(1.50)	2.34*	4.76(1.78)	4.05(1.46)	7.29***
P6: Ocean and humans are interconnected	3.01(1.26)	3.44(0.99)	-4.89***	2.76(1.00)	2.57(1.05)	2.04*	3.22(1.16)	2.67(1.02)	8.44***
P7: Ocean largely unexplored	0.82(0.68)	0.78(0.68)	0.59	1.06(0.70)	0.92(0.65)	2.40*	0.80(0.66)	0.99(0.69)	-4.81***
Total	28.43(7.96)	30.50(5.60)	-3.89***	25.52(5.46)	23.55(5.42)	3.99***	29.43(6.99)	24.52(5.66)	12.78***

Note. *:$p < .05$; **:$p < .01$; ***:$p < .001$.

23.55, respectively.

3.3. Relationships between parental education level, students' attitude, and ocean literacy

Measurement invariance across countries was a prerequisite for comparison. Table 3 presents the results of the analysis with the nested models. The RMSEA for each model was less than 0.08, and the CFI was greater than 0.90. These results indicated that the models adequately fit the sample data. The ΔRMSEA of the seven nested models was less than 0.07, which indicated measurement invariance across the Taiwanese and Japanese students. The hypothesized models for the Taiwanese and Japanese students were analyzed through MG-SEM; Fig. 3 presents the results. The model had adequate fit ($CFI = 0.976 > 0.90$, $RMSEA = 0.029 < 0.05$, and $SRMR = 0.043 < 0.05$).

Table 4 presents the indirect, direct, and total effects of P.EDU and ATT on OL under the condition of measurement invariance between Taiwan and Japan. ATT significantly impacted OL in both countries, with effect sizes of 0.08 and 0.26, respectively. The effect of P.EDU on ATT was nonsignificant in both countries, indicating that ATT does not moderate the effect of P.EDU on OL.

The direct effect of P.EDU on OL varied between countries. In Taiwan, the effect was directly related to OL, and the coefficient was 0.21 ($p < .001$). For Japan, the coefficient (0.14) was nonsignificant. The total effect of P.EDU on OL was stronger for Taiwanese students than for Japanese students: 0.208 and 0.145, respectively. The effect of ATT on OL was stronger for Japanese students than for Taiwanese students: 0.257 and 0.084, respectively.

4. Discussion

4.1. Ocean knowledge sources and ocean literacy performance

Students from Taiwan and Japan acquire knowledge from different sources because of the countries' respective marine education systems. Although marine education is similar in Taiwan and Japan in terms of content, each system has unique characteristics. In Taiwan, museums, TV, and classroom learning are students' primary sources of knowledge about the ocean. The study's results were similar to those of Chang [11]. It indicated that students who frequently visited marine biology museums and watched TV programs about marine science exhibited strong knowledge of marine science [11]. Japanese students mainly rely on school, TV, and classroom learning. The only difference in resources between the two countries is museums. Taiwan adopts an integrated approach to promoting marine education. Schools that do not prioritize marine education rarely integrate it into the curriculum, and teachers seldom teach it through an integrated approach. Marine education is more comprehensive in Japan than in Taiwan. After the 2011 Tohoku earthquake and tsunami, 83.2 % of Japanese students indicated that they considered knowledge of marine biology essential [4]. This has contributed to the advancement of marine education in Japanese schools and represents a key difference between the countries.

The Taiwanese students scored higher in ocean literacy than the Japanese students. The Taiwanese students had more correct answers and higher mean scores than the Japanese students in five of the seven principles. The result is quite interesting. Japanese elementary and high school textbooks found higher percentages of rivers, oceans, and water topics than Taiwan's textbooks [5]. However, Taiwanese students have a relatively high ocean literacy performance. This may have been because, in Taiwan, students are exposed to marine biology in the earth science curriculum beginning in the eighth grade. In middle school, the natural science curriculum includes certain marine biology-based content, and some teachers specialize in earth science. Furthermore, the items used to assess ocean literacy were based on the NOAA framework, and the seven principles mostly relate to marine biology. These factors may have resulted in the Taiwanese students outperforming the Japanese students in ocean literacy.

Although the performances of students in the two countries were different, both countries should be more committed to improving students' marine literacy. According to Stefanelli-Silva et al. [36], the marine life around schools, as well as informal marine courses on pollution, waste management and recycling can significantly improve students' awareness of ocean-related topics. In addition to in-person classes, online courses are also being delivered around the world, which helps students achieve the goal of improving their marine literacy [8]. For example, Fielding et al. [8] designed the "Exploring Our Oceans" online course. The impacts of this course include evidence of changed awareness and attitudes to ocean issues; increased applications and participation in undergraduate and postgraduate programs; development of communication and outreach skills in the postgraduate community. Both Taiwan and Japan are coastal countries. It is suggested that in addition to formal courses taught in schools, the marine environment around the school can be used to create more non-formal (support by research and academic organizations) or online courses, to break the rigid way of learning marine knowledge and improve students' marine literacy.

4.2. Influence of variables on the ocean literacy

The relationships between parental education level, students' attitude, and ocean literacy differed slightly between Taiwan and Japan. Previous studies have demonstrated that parental education level and

Table 3
Fit indices for multi-group analysis across countries.

Model	χ^2	*df*	CFI	RMSEA	SRMR	Model comparison	ΔRMSEA
Model 1 Configural invariance	186.43	102	0.976	0.027	0.043	-	-
Model 2 Invariance of factor loadings of measured variables	220.29	111	0.967	0.026	0.045	2 vs. 1	0.000
Model 3 Invariance of intercepts of measured variables	281.91	123	0.949	0.032	0.045	3 vs. 2	0.006
Model 4 Invariance of intercepts of latent variables	305.56	126	0.943	0.035	0.045	4 vs. 3	0.003
Model 5 Invariance of structure covariance	362.69	127	0.926	0.040	0.046	5 vs. 4	0.005
Model 6 Invariance of disturbances of latent variables	369.41	129	0.925	0.040	0.046	6 vs. 5	0.000
Model 7 Invariance of residuals variance of measured variables	450.32	141	0.902	0.043	0.046	7 vs. 6	0.003

Note. Taiwan group n = 6814, Japan group n = 493. df = degree of freedom; CFI = comparative fit index; RMSEA = root mean squared error of approximation; SRMR = standardized root mean square residuals.

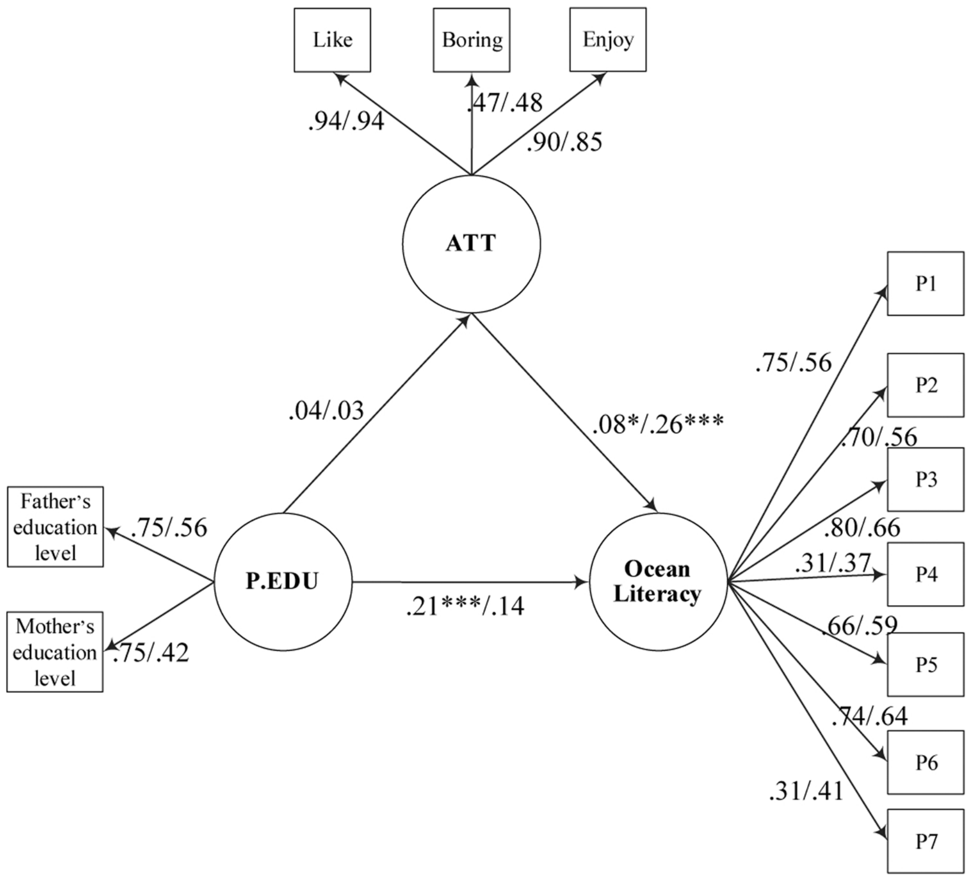

Fig. 3. Standardized estimates of relations of latent variables in hypothesized model. Chi-Square = 186.43, *df* = 102, *p*-value = < 0.001, RMSEA = 0.029, SRMR = 0.043, CFI = 0.976. *Note.* Taiwan group *n* = 681, Japan group *n* = 493 and total sample *n* = 1174. P. EDU = parental educational level; ATT = marine attitude; RMSEA = root mean squared error of approximation; SRMR = standardized root mean square residuals; The first value is for Taiwan group and second value is for Japan group.

Table 4
Direct, indirect, and total effects of latent variables on ocean literacy.

Effects	Paths	Taiwan	Japan
Direct	P.EDU → ATT	0.037	0.029
	P.EDU → OL	0.205	0.138
	ATT → OL	0.084	0.257
Indirect	P.EDU → OL	0.003	0.007
Total	P.EDU →ATT	0.037	0.029
	P.EDU →OL	0.208	0.145
	ATT → OL	0.084	0.257

Note. P.EDU = parental educational level; ATT = marine attitude; OL = ocean literacy.

income affect students' literacy and performance in science [18,19]. The present study also confirmed the same research results in Taiwan, where parental education level and students' attitude affected students' ocean literacy. Students with higher parental education level scored higher in terms of ocean literacy. This finding is also consistent with Kalender and Berberoglu [18] and Campbell et al. [20] Kalender and Berberoglu [18] demonstrated that parental education level strongly affects students' academic performance, and Campbell et al. [20] revealed that students with higher parental education level often earn higher grades. However, this may not apply to Japanese high school students. The effect of parental education level on ocean literacy was nonsignificant in this group. This result is consistent with the investigation of Tsai[14] and Mohammadpour[37]. Parental education had nonsignificant effect on students' OL and academic performance. Japanese students may be less susceptible to parental influence and have more academic autonomy than Taiwanese students; this should be further explored. In Taiwan and Japan, the more positive the students' attitude, the better their ocean literacy was. This result is similar to those of some previous studies [14, 26]. Students' attitude toward the ocean was a predictor of ocean literacy. However, parental education level did not affect ocean literacy through students' attitude.

4.3. Limitations and future research

A longitudinal study could be conducted to explore ocean literacy in students of other countries and ages to analyze ocean literacy in relation to each nation's marine education policies and to establish ocean literacy models for elementary, middle, and high school students. The results of such studies can be a reference for educators developing activities and policy makers for marine education. Studies can also widen the scope of data collection to entire nations. This study was conducted during the COVID-19 epidemic, and some schools were closed, which limited data collection to Japan's Tokyo and Tohoku regions; this is one limitation. After the pandemic, scholars should collect data more comprehensively to achieve a representative level of coverage. In addition, this study was limited to understanding students' access to marine knowledge and their performance in ocean literacy. Recent work has broadened the definition of ocean literacy and suggested that the concept comprises the following dimensions: (i) attitude, (ii) communication, (iii) behavior and (iv) activism, (v) connection to the ocean, (vi) emotions and empathy, (vii) motivations and (viii) access. [38,39] This should also be the focus of future research and will expand the study of ocean literacy.

5. Conclusions

This study examined ocean literacy in Taiwanese and Japanese high school students, the channels through which students acquire knowledge of marine biology, and the factors that affect ocean literacy. Taiwanese students significantly outperformed Japanese students in terms of ocean literacy. In addition, the channels through which students acquired knowledge are similar in both countries. In Taiwan, high parental education levels led to high ocean literacy scores, but this was not the case in Japan; these results may have been due to differences in the countries' marine education policies. The results provide a reference for high schools, teachers, and policy makers wishing to improve curricula, learning environments, and marine education policies in Taiwan and Japan.

CRediT authorship contribution statement

Liang-Ting Tsai: Conceptualization, Methodology, Supervision, Writing – original draft, Writing – review & editing, Formal analysis, Funding acquisition, Project administration. **Tsuyoshi Sasaki:** Data curation, Writing – original draft. **Chin-Kuo Wu:** Data curation, Writing – original draft. **Cheng-Chieh Chang:** Writing – original draft, Formal analysis, Writing – review & editing, Funding acquisition, Project administration.

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Data Availability

Data will be made available on request.

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