JOURNAL OF BALTIC SCIENCE EDUCATION

ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

THE IMPACTS OF A MARINE SCIENCE BOARD GAME ON MOTIVATION, INTEREST, AND ACHIEVEMENT IN MARINE SCIENCE LEARNING

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Abstract. *This research sought to explore how teaching utilizing a marine science-related board game affected students' motivation, interest, and achievement in marine science learning at the high school level. The research utilized an experimental design with pre-test and post-test measurements and a classroom setting, and included an experimental group containing 25 students and a control group containing 26 students. The experiment was carried out over the course of 12 lessons, with various questionnaires, including a marine science learning motivation (MSLM) inventory, a marine science learning interest (MSLI) inventory, and a marine science learning achievement (MSLA) inventory, being used as the measurement instruments. The research analysed the students' scores on these inventories using one-way analysis of ANCOVA. The main results of this research were as follows: 1) with regard to the MSLM inventory, the 'relevance', 'confidence', and 'total score' were significantly different between the two groups; 2) with regard to the MSLI inventory, the 'cognitions regarding marine science' were significantly different between the two groups; and 3) with regard to the MSLA, all of the dimensions including 'memory', 'understanding', 'high-level thinking', and 'total score' were significantly different between the two groups.*

Keywords: *board game teaching, learning interest, learning motivation, marine education, science education.*

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Introduction

For teachers, the best teaching method is one that can both teach students the information they need to learn and increase their willingness to learn. In recent years, many teachers have begun to eschew one-way teaching methods, instead enhancing their teaching methodologies with a variety of innovative tools while focusing more directly on the needs of students. Among the innovative methods increasingly used by teachers is teaching with board games. According to the curriculum guidelines for Taiwan for grades 1-12, marine education is one of four major education issues in Taiwan. As residents of an island nation surrounded by the ocean, it is imperative that students in Taiwan learn basic knowledge about the ocean. They should be equipped with ocean literacy for life, as well as a healthy respect for the natural environment in general, including the ocean. To this end, the objectives of 'Being close to the ocean', 'Loving the ocean', and 'Knowing the ocean' are regarded as important aspects of marine education that can have a positive influence on students' marine literacy. With such goals in mind, the use of a board game teaching method in a marine science course to enhance students' motivation, interest, and achievement in marine science learning was the primary aim of this research.

Learning is a process that frequently involves social interactions, with the construction of various forms of learning relying on the interactions between learners and their learning environments. Students in a given learning situation must often take the initiative to explore and solve problems, identifying the relevant information and its structure. In doing so, they can further construct new knowledge and skills that allow them to address new challenges (Yang & Duan, 2015). Most teachers in Taiwan typically provide students with a one-way introduction to a given course, and this approach makes it difficult for students to acquire and integrate the relevant concepts, while such learning difficulties can, in turn, reduce students' willingness to learn. Motivation plays an important role in influencing learning and achievement in students. In recent years, in order to improve students' learning motivation and enhance the effect of motivation on learning, various teaching designs and situational tools have emerged in the education field. Keller (1987) proposed a theory of motivation that views it as being comprised of four main

https://doi.org/10.33225/jbse/19.18.907

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

aspects: attention, relevance, confidence, and satisfaction (ARCS). The current research, in turn, used Keller's ARCS motivational theory strategies to accomplish its goals regarding the teaching of marine science.

A board game combining many marine science education concepts was designed. By playing this board game, students cannot only learn about marine science concepts but also gain a more profound understanding of their relevance. According to the rules of the game, students are required to clarify the relevant concepts in order to achieve a high ranking in the game. These game rankings are different from test scores and effectively provide students with greater willingness and interest in learning the marine science concepts that are required to succeed in the game. The marine science board game cultivates students' marine literacy in a somewhat 'virtual' manner by casting them in the role of sea creatures who have a strong interest in learning as much as possible about the ocean. Using the board game, this research effectively sought to compare the board game teaching method with the traditional expository teaching method to see how the board game method affected students' motivation, interest, and achievement in marine science learning.

Various educators have suggested that board games could potentially serve as useful pedagogical tools. Akl, Pretorius, Sackect, Erdley, Bhoopathi, Alfarah, and Schünemann (2010) pointed out that using educational games had the potential to improve medical education outcomes, but they did not confirm a positive effect of games on knowledge. Anyanwu (2014) reported that high proportions of the students in a game group indicated that the game in question was entertaining, highly informative, encouraged teamwork, and improved their attitudes and perceptions regarding the subject of gross anatomy. Bayir (2014) also indicated that playing games might help students reinforce and review key concepts. In short, given that playing games appears to be an essential aspect of the human experience, the use of educational games as teaching tools may be a natural choice for teachers as they strive to help students achieve the desired learning outcomes (Roberts, 2010).

Chen and Wong (2017) conducted a literature review regarding the use of board games in Taiwan from 2002 to 2016, and Table 1 shows the distribution of the different fields in which board games were used. As indicated there, the review found that board games were primarily used in the field of education in Taiwan. Moreover, the review found that enhancing social and emotional abilities and English language skills were the top two aims for the use of board games within the education field. Meanwhile, only one research that they reviewed (Lu & Lu, 2013) used a board game for the purposes of marine and environmental education with elementary school students. Typically, board game-based teaching consists of a teaching method in which a board game serves as the pedagogical tool used in the class.

Table 1. A summary of the fields in which board games were used in studies in Taiwan from 2002 to 2016, *N*=137.

Field	N	%
Education	82	59.9
Game design	29	21.2
Sociology / Psychology	21	15.3
Social work	3	2.2
Enterprise management	1	0.7
Game history	1	0.7
Total	137	100.0

UNESCO (United Nations Educational, Scientific and Cultural Organization, UNESCO) published a report in 1988 in which marine education was separated into the subfields of specialized marine science teaching and general marine science education. The former is a major focus in the training of professional marine science specialists with unique skills, while the latter is useful for teaching people to view themselves as global citizens with respect to the ocean. In recent decades, Japan, the United States, and Australia have paid increasing attention to basic marine knowledge and literacy, not only by including marine culture in marine education but also by placing a greater emphasis on marine-related human resources development in the marine science field. Given climate change-related problems like global warming, enhancing the marine literacy of people has increasingly been seen as a goal of more and more nations in recent years.

https://doi.org/10.33225/jbse/19.18.907

In October of 2005, the NOAA (National Oceanic and Atmospheric Administration), COSEE (Centers for Ocean Sciences Education Excellence), and NMEA (National Marine Educators Association) published a list of the 7 essential principles and 44 fundamental ocean science concepts that currently define ocean science literacy. Ocean literacy serves as a national standard for marine education, and is defined as 'understanding the ocean's influence on you and your influence on the ocean'. According to the COSEE, a person has ocean literacy if he or she 'can communicate about the sea in a meaningful way', 'can make informed and responsible decisions regarding the ocean and its resources', and 'understands the essential principles and fundamental concepts about the functioning of the ocean'. The seven essential principles are: 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 Earth habitable; 5) The ocean supports a great diversity of life and ecosystems; 6) The ocean and humans are inextricably interconnected; and 7) The ocean is largely unexplored. In the NMEA's Ocean Literacy Campaign Special Report #3, the work of dozens of agencies and hundreds of individuals to bring ocean sciences into the mainstream of both formal and informal education is discussed. The ocean literacy scope and sequence for grades K-12 is presented in this special report as a series of 28 conceptual flow diagrams that represent and organize the ideas of the seven principles into four grade bands: K-2, 3-5, 6-8, and 9-12 (NMEA, 2010).

In Taiwan, the government published the first ocean policy white paper in 2006. After that, the Ministry of Education published its own white paper on ocean education policy in 2007. The following year, the ministry set the marine education curriculum guidelines for both primary and secondary schools, with the full implementation of those guidelines following three years later in 2011. A total of five main topics, specifically, marine science, marine resources, marine culture, marine society, and marine leisure, are included in the competence indicators for marine education in Taiwan for the grades 1-9 curriculum. The Ministry of Education detailed its expectations with respect to the development of educational efforts to ensure that students have an appropriate understanding of marine topics in a white paper on marine education policy published in 2017, including a discussion of its expectations on how to make Taiwan a modern maritime nation with an appropriate civilized texture and cultural aesthetic, as well as on how to build consensus among the people.

The concepts of ocean literacy corresponding to the marine education competence indicators in the grades 1-9 curriculum for Taiwan are classified into the two topics of marine science and marine resources. Thus, the domain of marine science education in the current research involves the concepts of ocean literacy and the two themes of the marine education competence indicators in Taiwan. This research developed a marine science educational course for high school students and designed a board game (which was named 'M.O.S.' as an abbreviation for 'marine, ocean, sea') combining the path of currents in the ocean and other marine science concepts and emphasizing the garbage patch problems in the ocean as the primary educational tool in the course. The course and board game were used to determine the impacts of the game on students' motivation, interest, and achievement in marine science learning.

Focus and Aim of Research

The participants were ninth-grade students in Taipei City, and a series of marine science education lessons using the board game teaching method were planned and conducted to understand the students' learning motivation, interest, and achievement. The aims of this research were as follows:

1. Can the board-game teaching improve students' learning motivation in marine science?
2. Can the board-game teaching improve students' learning interest in marine science?
3. Can the board-game teaching improve students' learning achievement in marine science?

Based on the above questions, the goals of this research were as follows:

1. To determine if there were statistically significant differences in marine science learning motivation between students who were taught using the marine science board game compared to those who were taught through marine science expository teaching.
2. To determine if there were statistically significant differences in marine science learning interest between students who were taught using the marine science board game teaching compared to those who were taught through marine science expository teaching.
3. To determine if there were statistically significant differences in marine science learning achievement between students who were taught using the marine science board game teaching compared to those who were taught through marine science expository teaching.

https://doi.org/10.33225/jbse/19.18.907

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Research Methodology

General Background

This research used board game teaching with a marine science educational course to determine the impacts of the teaching on high school students' learning motivation, interest, and achievement. According to the aforementioned white paper on marine education policy promulgated by the Ministry of Education (2017), in Taiwan, 'Education needs to be reformed and innovated in the light of marine development so that the people who are cultivated can devote themselves to the innovation and development of the oceans'. Therefore, this research took marine science as its theme, using the interesting characteristics of the board game as the marine science teaching method in an experimental group in the hopes of enhancing the students' learning motivation, learning interest, and learning achievement in marine science.

The structure of this research included four kinds of variables: independent variables (IV), dependent variables (DV), control variables, and covariates. The independent variables were the teaching methods, which consisted of the board game-based instruction in the experimental group and expository education in the control group. There were four kinds of dependent variables, including a learning motivation inventory, a learning interest inventory, a multiple-choice marine science test, and a marine science propositional concepts sentence making test that served as the post-test. The control variables sought to reduce the interference of other factors in the experiment, which had to be monitored in the research. The control variables in the research included the understanding of the students regarding earth science subjects, the teaching materials, the teaching time and progress, and so on.

The covariates were sufficient to affect the variables in terms of the experimental results, so it was necessary to perform a covariate analysis of the statistics so as to exclude the impact of the covariates and minimize the experimental error. The covariates of the research included the average scores of the students in earth science subjects, the pre-test learning motivation inventory results, the learning interest inventory results, the multiple-choice marine science test results, and the propositional concepts sentence making test results. The research process included the pre-testing and post-testing of the two groups included in the experiment. Through the data collection and statistical analysis, the construction of the reliability and validity of the assessment tool, the current situation analysis, and the forecast analysis, the results could finally be utilized to propose various recommendations.

Sample

Only students whose parents were notified of the purpose of the research and provided informed consent were eligible to take part in this research. Due to the need for informed consent from parents, limited resources, and other specifics of the experimental method used in the research, only a relatively small sample of students ultimately took part in the research. Specifically, the participants consisted of 51 high school students in two classes at a school in Taipei City. The experiment was used in the research, and it included an experimental class containing 25 students and a control class containing 26 students. The participants were selected based on the average scores for the earth science subject in the preceding semesters. They were grouped into teams according to the scores by using different grouping before the marine science course teaching so that each cluster was close to each group. The experimental class was taught in the marine science course using a board game teaching programme, and the control class was taught using a teaching programme. The total duration of each teaching programme was six weeks, during which 12 classes, each 45 minutes in length, were conducted. In the board game teaching programme, the students were taught the central concepts of the marine science course unit through discussion (including question-and-answer sessions), cooperative learning, and the board game teaching itself. In the expository teaching programme, the students were taught the central concepts of the unit through explanations of the educational materials supplemented by discussion (including question-and-answer sessions) and cooperative learning. The two programmes only differed in terms of the teaching methods used, while the progress of teaching and the course content were the same in both programmes. Relatedly, the board game was not used as an educational tool in the expository teaching programme. Instead, a marine science article reading activity was employed in the expository teaching programme.

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Instruments and Procedures

One of the research instruments used was a marine science questionnaire that included a marine science learning motivation (MSLM) inventory, marine science learning interest (MSLI) inventory, and marine science learning achievement (MSLA) examination. Another was the marine science course design, which contained the marine science board game teaching programme and the marine science expository teaching programme.

The marine science learning motivation (MSLM) inventory and marine science learning interest (MSLI) inventory were designed using the Likert scale (1932) with 5-point Likert scale as per a research by Dawes and John (2008). They pointed out that inventories with five, seven, or ten Likert items had similar results in terms of the data obtained.

In order to improve the content validity and reliability of the questionnaire with the MSLM inventory, MSLI inventory, and MSLA examination, the research prepared the first draft of the questionnaire with the help from seven experts and scholars who assisted in the identification of the content representation and appropriateness to ensure the content validity. Once the survey was complete, the research conducted a pilot test with 122 ninth-grade high school students.

The marine science motivation of the students was measured using the MSLM inventory, which included four dimensions: 1) attention, 2) relevance, 3) confidence, and 4) satisfaction. For each item in the MSLM inventory, a respondent could choose from five numerical options, including 5 for 'definitely agree', 4 for 'agree', 3 for 'unsure', 2 for 'disagree', and 1 for 'definitely disagree'. The motivation inventory scores were then tallied, with the participants with higher scores being regarded as having higher levels of the various dimensions.

The marine science interest of the students was measured using the MSLI inventory, which included the following dimensions: (1) feelings about the ocean, (2) cognitions regarding the ocean, and (3) the actions of marine science. For each item in the MSLI inventory, a respondent could choose from five numerical options, including 5 for 'definitely agree', 4 for 'agree', 3 for 'unsure', 2 for 'disagree', and 1 for 'definitely disagree'. The interest inventory scores were then tallied, with the participants with higher scores being regarded as having higher levels of the various dimensions.

On the basis of information included in Marine magazine (2014), a periodical which was published by the National Museum of Maritime Science and Technology in Taiwan; Flotsametrics and the Floating World: How One Man's Obsession with Runaway Sneakers and Rubber Ducks Revolutionized Ocean Science (Ebbesmeyer & Scigliano, 2013), which was published by *Bookzone*; the Marine Education Book textbook, which was published by *EduBook* (2012); the environmental literacy teaching guidelines in One Ocean (2013), which was published by National Geographic; and the Taiwan General Scholastic Ability Test for 2006-2015, this research designed the MSLA examination to be divided into two parts, namely, a multiple-choice marine science test and a marine concepts sentence making test. The former included 15 multiple-choice marine science questions which covered three cognitive process dimensions, namely, 'memory' (4 items), 'understanding' (4 items), and 'high-level thinking' (7 items), which involved the 'apply', 'analyse', and 'create' concepts of the revised Bloom edition (Anderson *et al.,* 2001). The latter used the method of concept maps for sentence making, including a total of ten sentences using 50 marine science terms (Chang, Yang, & Low, 2014). The items in the multiple-choice marine science test were modified using the earth science textbook for the high school and the publications mentioned above. The items were classified as covering the dimensions of memory, understanding, and high-level thinking, which were sourced from the Bloom revised edition that includes the dimensions of 'memorize', 'understand', 'apply', 'analyse', 'evaluate', and 'create' (Anderson, Krathwohl, Airasian, Cruikshank, Mayer, Pintrich, Raths, & Wittrock, 2001).

The latter part of the MSLA examination listed 50 marine science concept terms about the underlying marine science concepts, such as sea water systems, marine ecology, marine science and technology, marine life, and marine pollution. It also let the students check and choose from some of the concepts they knew to make the sentences. It was recommended that each sentence contain at least two marine science terms from the list. The propositional concept sentences, which were constructed according to the concepts of Stoddart et al. (2000), included the three dimensions of an open proposition, namely, accuracy, depth of explanation, and complexity, in the overall score. Each sentence could score a maximum of 5 points and a minimum of 0 points to determine the overall MSLA score. The statements used to score the quality of each sentence in terms of the three dimensions are shown below, and are also shown with examples in Table 2.

1. Accuracy was scored in terms of four options: 'Scientifically accurate', 'Common knowledge', 'Affective', and 'Inaccurate'.
2. Depth of explanation was scored in terms of two options: 'Higher-order explanation' and 'Descriptive'.
3. Complexity was scored in terms of two options: 'Compound' and 'Simple'.

https://doi.org/10.33225/jbse/19.18.907

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Table 2. The propositional concepts sentence making scoring system.

Variable	Category	Example	Score
Accuracy	Scientifically accurate	Pressure increases with depth in the ocean	5
	Common knowledge	Whales live in the ocean	3
	Affective	Dolphins are beautiful	1
	Inaccurate	Sharks are mammals	0
Depth of explanation	Higher-order explanation (answers 'how' or 'why')	Anglerfish have bioluminescent danglers above their mouths that are used to attract prey	5
	Descriptive	Anglerfish have bioluminescent danglers	3
Complexity	Compound	Shining tube shoulders have photospheres on their undersides and heads	5
	Simple	Shining tube shoulders have photospheres	3

Reliability

The KMO (Kaiser-Meyer-Olkin, KMO) score of the final marine science learning motivation inventory was .916. The KMO score of the final marine learning interest inventory was .938.

With respect to the MSLM inventory, the pilot test was used to measure the questionnaire's Cronbach's α values in terms of the four marine learning motivation dimensions, which were, respectively: (1) attention: .96; (2) relevance: .93; (3) confidence: .93; and (4) satisfaction: θ.96. The value for the overall inventory was θ.98. In the pre-test, the Cronbach's α values in terms of the four marine learning motivation dimensions were, respectively: (1) attention: .88; (2) relevance: .85; (3) confidence: .84; and (4) satisfaction: .92. The value for the overall inventory was .95. In the post-test, the Cronbach's α values in terms of the four marine learning motivation dimensions were, respectively: (1) attention: .92; (2) relevance: .82; (3) confidence: .82; and (4) satisfaction: .92. The value for the overall inventory was .96.

With respect to the MSLI inventory, the pilot test was used to measure the questionnaire's Cronbach's α values in terms of the three marine learning interest dimensions, which were, respectively: (1) feelings about the ocean: .93; (2) cognitions regarding the ocean: .95; and (3) actions of marine science: .92. The value for the overall inventory was .96. In the pre-test, the Cronbach's α values in terms of the three marine learning interest dimensions were, respectively: (1) feelings about the ocean: .88; (2) cognitions regarding the ocean: .95; and (3) actions of marine science: .88. The value for the overall inventory was .93. In the post-test, the Cronbach's α values in terms of the three marine learning interest dimensions were, respectively: (1) feelings about the ocean: .72; (2) cognitions regarding the ocean: .82; and (3) actions of marine science: .86. The value for the overall inventory was .90.

The pilot test of the MSLA multiple-choice test had 19 items, and the average item difficulty index was .46, while the average item discrimination was .42. A test question with a difficulty index above .4 and discrimination between 0.4~0.6 is an excellent test question (Chen & Wu, 1994). The research deleted those items with a weak item difficulty index and discrimination. So, the test then had an average item difficulty index of .52 in the post-test, while the average item discrimination was .50.

The difficulty index and discrimination of each item in the marine science achievement test in this researchfell within the aforementioned range, and the average difficulty index and discrimination were also in line with this range. That showed that the item difficulty index and discrimination of the MSLA multiple-choice test were good. Also, the KR20 value of the multiple-choice items in the MSLA pilot test was .67. Meanwhile, the value in the pre-test was 0.64, and the value in the post-test was .60. A reliability value above .55 indicates a reliable consistency (Ebel, 1972). So, all of the achievement tests had reliable reliability.

The total score of the marine science propositional concepts sentence making test was 150 for all ten sentences. Although the score was based on a scoring system table, it was quickly affected by the given student's subjective consciousness. To reduce this effect and enhance the reliability of the score, the research randomly selected 10 of the 51 learning achievement sentence making tests of the students that had been scored by teacher A. Then another earth science teacher, teacher B, re-scored those 10 sentence making tests. The research then conducted

https://doi.org/10.33225/jbse/19.18.907

a correlation analysis of the scores from teacher A and teacher B, and the correlation coefficient was .997. There was, in other words, a significant positive correlation between the scores from the two teachers. This showed that the marine science propositional concepts sentence making test had excellent scoring reliability.

Marine Science Course Design

The marine science course content was based on 'marine debris' as the central theme, and related scientific knowledge was designed for inclusion into the course. To help the students understand the global issue, the research designed the course to cover the 'garbage patch' and 'marine debris' issues. The designed teaching course was based on the 5E learning cycle teaching strategies, which were developed by Trowbridge and Bybee (1990) according to the constructivist view of the BSCS (Biological Science Curriculum Study) in the United States. The five processes of this teaching model are engagement, exploration, explanation, elaboration, and evaluation. The marine science course schedule is shown in Table 3 below.

Table 3. Marine science course schedule.

Week	Unit
1	The Importance of the Ocean
2	Ocean Current and Circulation
3	Marine Debris
4	The Garbage Patch in the Ocean
5	The Impact of Marine Garbage on Ecology
6	The Way of Protecting the Ocean

The research designed a board game called 'M.O.S.' as the teaching tool. The board game was developed to cover the garbage patch and marine debris issues, with the concepts of extreme wind-driven currents and thermohaline circulation (THC) included in the overall background (Figure 1). According to Feller's (2007) 110 misconceptions about the ocean and marine science knowledge, marine garbage cards (168 pieces), ocean event cards (40 pieces), and ocean misconception cards (40 pieces) were made. In the process of the game, students could become familiar with the major ocean currents and thermohaline circulation (THC) around the world and learn the impacts of marine garbage in the ocean, as well as much of the associated ocean knowledge, helping them to enhance their understanding of and literacy regarding the ocean. The rules of the M.O.S. game were as follows:

1. Taking ten garbage cards and selecting 'IN' as the beginning icon (on the equatorial counter current), each group starts with 80 points.
2. Everyone calls out 'Marine, ocean, sea!' to determine the number of steps of the next group (0~3); if 0 steps was called, then the group stays in place and repeats the action on the icon.
3. If you stop on the icon numbered N, then take N garbage cards. If you stop on the arrow icon, choose to save animals or not by using the garbage cards.
    (1) Perform animal rescue: different marine animals can be rescued with different garbage cards (+30 points):
        (a) Whales: plastic bags, plastic bottles, plastic boxes, plastic sheeting
        (b) Turtles: straws, forks, plastic bags
        (c) Seals: fishing nets, rope, rubber products
        (d) Seabirds: lighters, canned food, tobacco
        (e) Penguins: plastic caps, plastic particles, plastic debris
    (2) Don't save the animals (-30 points).
4. If you stop on the warm current icon, take an ocean event card. If you stop on the cold current image, take a misconception card to answer the question. A correct answer earns 30 points, while a wrong answer loses 30 points.
5. When passing the yellow star icon, the player can choose which way to go.
6. If you make a full circulation in the area and return to the grey icon, you can pass to another field via the grey route.

https://doi.org/10.33225/jbse/19.18.907

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

7. When players meet each other on the same icon, their points are averaged together.
8. After ten rounds, the players calculate the scores by themselves, and the player with the highest score is the winner.
9. Total score = points - (number of garbage cards X 3)

Figure 1. Background of the M.O.S. board game.

The M.O.S. board game activity was played with several groups, with the teacher acting as the director to guide the teams during play. The steps taken by a group were determined by the catchphrase 'Marine, ocean, sea!', with one member from each of the other groups making a gesture (0 to 3) and the sum of those gestures determining the steps of the group. This approach increased the fun and participation in the game among the teams. The similarities and the differences in the course with respect to the two teaching programmes are shown below in Table 4.

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Table 4. The similarities and the differences in the marine science course between the board game teaching method and the expository teaching method.

		Board Game Teaching Method	Expository Teaching Method
Similarities	Participants	Ninth-grade students in high school	
	Teaching hours	45 minutes/class for 12 classes, 540 minutes in a total.	
	Teaching location	Classroom	
	Teacher	The researcher	
	Purpose	Enhance the motivation, interest, and achievement in marine science learning.	
	Teaching model	5E Learning Cycle	
	Teaching progress	Unit 1~6 for 12 lessons	
	Teaching strategies	Questions and answers, group discussion, reward system, multimedia teaching tools	
	Teaching materials	Self-compiled teaching PowerPoint slides, worksheets	
Difference	Education activities	Board game activities	Reading marine science articles
	5E-Engagement	Focusing on existing global issues – the garbage patch	Focusing on a broad range of marine science knowledge
	5E-Exploration	Student-centered	Teacher-centered
	5E-Explanation	Students are more autonomous	Students are less autonomous
	5E-Elaboration	Initiative	Passive
	5E-Evaluation	The score of the game	Worksheet score
	Features	Learning with fun in the board game	Emphasizing the principles and details of MS knowledge
	Other	Enhance students' ability to express themselves and work in teams	Learn accurately for the MS course

Data Analysis

Cronbach alpha coefficient was used to determine the reliability of the tests. The one-way ANCOVA was used to evaluate differences between pre-test score and post-test scores of MSLM inventory, MSLI inventory, MSLA inventory, and marine science propositional concepts sentence making test. The significance level was set at p=.05.

Research Results

The experimental group and the control group students' scores in the pre-test for the learning motivation inventory were the covariate, with the teaching methods serving as the independent variable and the post-test scores serving as the dependent variables. The research conducted a one-way analysis of covariance (one-way ANCOVA) with the independent sample, and the results are presented in Table 5.

https://doi.org/10.33225/jbse/19.18.907

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Table 5. The covariance of MSLM.

Motivation Dimensions	Source of Variation	*SS*	*df*	*MS*	*F*	*p*
Attention	Between groups	39.136	1	39.136	1.881	.177
	Within groups	998.752	48	20.807		
Relevance	Between groups	92.386	1	92.386	6.852	.012
	Within groups	647.231	48	13.484		
Confidence	Between groups	59.082	1	59.082	6.409	.015*
	Within groups	442.458	48	9.218		
Satisfaction	Between groups	65.552	1	65.552	3.007	.089
	Within groups	1046.337	48	21.799		
Total	Between groups	997.024	1	997.024	4.468	.040*
	Within groups	10710.720	48	223.140		

*(df= Degree of Freedom, MS= Mean Square) *p <.05 **p <.01 ***p <.001*

The experimental group and the control group students' scores in the pre-test for the learning interest inventory were the covariate, with the teaching methods serving as the independent variable and the post-test scores serving as the dependent variables. The research conducted a one-way analysis of covariance (one-way ANCOVA) with the independent sample, and the results are presented in Table 6.

Table 6. The covariance of MSLI.

MSLI Dimensions	Source of Variation	*SS*	*df*	*MS*	*F*	*p*
Feelings	Between groups	5.730	1	5.730	0.691	.410
	Within groups	398.229	48	8.296		
Cognition	Between groups	57.692	1	57.692	4.183	.046*
	Within groups	662.096	48	13.794		
Action	Between groups	34.101	1	34.101	1.897	.175
	Within groups	862.902	48	17.977		
Total	Between groups	4.823	1	4.823	0.047	.828
	Within groups	4876.228	48	101.588		

*(df= Degree of Freedom, MS= Mean Square) *p <.05 **p <.01 ***p <.001*

Table 7 shows the results of the statistical data comparison between the experimental group and the control group for the MSLA test. In the memory dimension, $F = 9.921$, $p = .003$ (<0.05), which indicated a significant difference. In the understanding dimension, $F = 5.109$, $p = .028$ (<0.05), which indicated a significant difference. In the high-level thinking dimension, $F = 10.464$, $p = .002$ (<0.05), which indicated a significant difference. For the total score, F = 158.338, $p = .001$ (<.05), which also indicated a significant difference. In summary, all the dimensions of the MSLA test had significant differences. Therefore, the statement that 'the board game teaching method can improve students' achievement in marine science learning' should be accepted.

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Table 7. The covariance of MSLA test.

Achievement Test Dimensions	Source of Variation	*SS*	*df*	*MS*	*F*	*p*
Memory	Between groups	14.144	1	14.144	9.921	.003**
	Within groups	68.432	48	1.426		
Understand	Between groups	6.347	1	6.347	5.109	.028*
	Within groups	59.635	48	1.242		
High-level thinking	Between groups	37.752	1	37.752	10.464	.002**
	Within groups	173.168	48	3.608		
Total	Between groups	158.338	1	385.184	158.338	.001**
	Within groups	606.257	48	12.630		

*(df= Degree of Freedom, MS= Mean Square) *p <.05 **p <.01 ***p <.001*

The results of the statistical data comparison between the experimental group and the control group for the marine science propositional concepts sentence making test are shown in Table 8. In the accuracy dimension, F = 8.424, p = .006 (<0.05), which indicated a significant difference. In the depth of explanation dimension, F = 1.935, p = .171 (>.05), which indicated a significant difference. In the complexity dimension, F = .215, p = .645 (>.05), which indicated a significant difference. For the total score, F=2.811, p=.100 (>.05), which also indicated a significant difference.

Table 8. The covariance of marine science propositional concepts sentence making test.

Propositional Concepts Sentence Making Dimensions	Source of Variation	*SS*	*df*	*MS*	*F*	*p*
Accuracy	Between groups	400.694	1	400.694	8.424	.006**
	Within groups	2283.236	48	47.567		
Depth of explanation	Between groups	75.953	1	75.953	1.935	.171
	Within groups	1883.982	48	39.250		
Complexity	Between groups	8.219	1	8.219	0.215	.645
	Within groups	1838.654	48	38.305		
Total	Between groups	944.565	1	944.565	2.811	.100
	Within groups	16128.98	48	336.020		

*(df= Degree of Freedom, MS= Mean Square) *p <.05 **p <.01 ***p <.001*

In the MSLA, the propositional concepts of the sentences were classified according to the aforementioned seven ocean literacy principles. The sentences covered the scope of the principles in 1-B Geologic Features, 1-C Ocean Circulation, 3-A Weather and Climate, 3-B Global Climate Change, 5-A Primary Productivity, 5-B Ecosystem, 6-A Use of the Ocean, 6-D Human Impact on the Ocean and Atmosphere, 6-E Responsibility, and Advocacy for the Ocean. Some sentences that did not involve the marine science knowledge field would be described as 'other knowledge'. Some sentences that made sense but did not include any relevant educational materials would be described as 'description'. The results of the pre-test and the post-test are shown in Table 9.

https://doi.org/10.33225/jbse/19.18.907

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Table 9. Ocean literacy of propositional concepts sentence making.

	EG Pre-Test (%)	CG Pre-Test (%)	EG Post-Test (%)	CG Post-Test (%)	Total Pre-Test (%)	Total Post-Test (%)
1-B Geologic Features	1.60	1.54	3.20	3.46	1.57	3.33
1-C Ocean Circulation	8.85	6.15	10.00	8.46	7.65	9.22
3-A Weather and Climate	0.40	0.77	1.60	1.92	0.59	1.76
3-B Global Climate Change	1.20	1.15	0.80	0.77	1.18	0.78
5-A Primary Productivity	9.20	7.31	6.40	6.15	8.24	6.27
5-B Ecosystem	5.20	2.69	5.20	8.46	3.92	6.86
6-A Use of the Ocean	0.40	0.38	0.80	1.15	0.39	0.98
6-D Human Impact on the Ocean and Atmosphere	4.40	3.85	15.20	16.54	4.12	15.88
6-E Responsibility and Advocacy for the Ocean	1.60	3.85	6.00	5.77	2.75	5.88
Other knowledge	11.20	13.46	20.80	20.77	12.35	20.78
Description	14.40	29.23	12.80	9.23	21.96	10.98
Error	8.80	10.77	1.20	0.00	9.80	0.59
Null	32.40	18.85	16.00	17.31	25.49	16.67

(EG= Experimental Group with 25 students, CG= Control Group with 26 students)

When the sentence was a narrative with facts, it was evaluated as 'knowledge'. When the sentence was about transferring ideas or the protection of the marine environment, it was evaluated in terms of 'attitude'. When the sentence was an expression of emotional factors, it was evaluated in terms of 'feelings'. Each of these three dimensions could exist in a single sentence at the same time. Meanwhile, a sentence with the expression of an incorrect statement would be regarded as a misconception. The results of the marine science expressions of meaning in the propositional concepts sentence analysis in terms of knowledge, attitudes, feelings, and misconceptions in the pre-test and post-test are presented in Table 10.

Table 10. Expressions of meaning in propositional concepts sentence making.

	EG Pre-Test (%)	CG Pre-Test (%)	EG Post-Test (%)	CG Post-Test (%)	Total Pre-Test (%)	Total Post-Test (%)
Knowledge	53.60	63.08	79.20	74.23	58.43	76.67
Attitudes	0.00	1.54	0.80	2.31	0.78	1.57
Feelings	1.60	3.08	0.80	0.38	2.35	0.59
Knowledge and& Attitudes	1.20	0.38	1.60	3.46	0.78	2.55
Attitudes and& Feelings	0.40	0.77	0.00	0.77	0.59	0.39
Knowledge and& Feelings	0.00	1.15	0.40	0.77	0.59	0.59
Knowledge,&Attitudes, and& Feelings	0.40	0.38	0.00	0.7	0.39	0.39

https://doi.org/10.33225/jbse/19.18.907

	EG Pre-Test (%)	CG Pre-Test (%)	EG Post-Test (%)	CG Post-Test (%)	Total Pre-Test (%)	Total Post-Test (%)
Misconceptions	10.40	10.38	0.01	0.00	10.39	0.59
Null	32.40	19.23	16.00	17.31	25.69	16.67

(EG= Experimental Group with 25 students, CG= Control Group with 26 students)

Discussion

For the MSLM inventory, the two groups of students did not appear to have significant differences in the attention dimension. Keller (1987) divided attention in teaching into six strategies: incongruity, conflict, concreteness, variability, humor, inquiry, and participation. Learning motivation is concerned with the acquisition and maintenance of students' attention, and the biggest challenge relates to how to keep such attention. As detailed in the statistical data, the scores of the students for the MSLM did not indicate large differences between the pre-test and post-test, and the average total scores for both were greater than half of the maximum possible total score. Therefore, this research speculated that the marine science course itself had the effect of attracting the students' attention. In other words, there was no noticeable difference between the board game teaching method and the expository teaching method.

In the relevance dimension, there was a significant difference between the two groups of students. The experimental group thought that marine science was much more relevant to themselves than the control group. Keller (1987) developed six strategies regarding relevance: experience, present worth, future usefulness, need matching, modeling, and choice. If the students understand what they learn and can connect it to their lives, that can produce learning motivation. Therefore, making students think that what they have learned is worthwhile can convince them that the course or materials are closely related to their future lives. It might be that the marine science board game focused on the source of garbage in daily life, and thus always reminded the students of the human relevance of the ocean. It also let the students know how the causes of the problem are attributed to the people in the world. So, the students taught with the board game teaching method thought that the course content was much more relevant to themselves than did those taught with the other method.

In the confidence dimension, there was also a significant difference between the two groups; the experimental group expressed the view that the marine science courses could give them more confidence. Keller (1987) divided the strategies for raising confidence into five strategies: requirements, difficulty, expectations, attributions, and self-confidence. These strategies allow students to know that they will learn the course content successfully through their efforts. If they have faith in that outcome when engaging in the activities, it can maintain their self-confidence. It might be that the students in the experimental group had the confidence to propose radical solutions to the ocean problems that human beings have produced. Therefore, the students in the experimental group exhibited the effect of learning with confidence in terms of their marine science learning motivation.

With regard to the satisfaction dimension, the difference between the two groups of students was not significant. Keller (1987) indicated that satisfaction strategies include natural consequences, unexpected rewards, positive outcomes, negative influences, and scheduling. These strategies give learners the opportunity to show their strengths and obtain internal and external feedback in appropriate ways, establishing personal achievements and satisfaction. The most direct way to provide students with a sense of satisfaction is to give them the opportunity to express their knowledge or actions within the classroom or other environments by themselves. Relatedly, it might be that although the board game teaching method and the expository teaching method led students to discover and learn about the problems of the ocean, the students did not achieve sufficient performance to feel satisfied. So, the two groups of students had no significant improvement in the dimension of satisfaction.

In the total score for learning motivation, there was a significant difference between the two groups of students. ARCS was the learning motivation model used to capture the attention of the learners first, through the combination with experience, so that the students would understand the things they had learned, understand how they applied to them personally, and then produce positive learning willingness. At the same time, they could also understand that their efforts could achieve knowledge of the materials of the teaching content and establish their confidence

https://doi.org/10.33225/jbse/19.18.907

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

regarding that knowledge. Finally, they could obtain the satisfaction of learning and a sense of accomplishment. Although there were some gaps in the overall process, it was undeniable that the marine science board game did achieve some of the motivation needed to enhance their marine science learning. Overall, then, it is suggested that the board game teaching method can probably improve students' motivation in marine science education.

For the MSLI inventory, the two groups of students did not appear to have significant differences in the 'feelings about marine science' dimension. The difference between the two groups of students was also not significant for the 'actions of marine science' dimension. Some studies have found that students' feelings and attitudes towards science subjects, scientific teaching, and science learning experience tend to worsen as they rise through the grades in school. In particular, most students who thought that science was interesting and useful during primary education tend to not feel so positively toward science in middle school (Yager & Penick, 1986). The 'actions of marine science' dimension in this research was similar to learning attitude. Attitude is a kind of psychological status determined by past experiences, which affect the individual's responses to objects, things, and situations. It has the influence of guiding both action and inaction (Chang, Liu, Chen, Huang, Lai, & Yeh, 2017). Relatedly, the reason that the students in this research did not exhibit a difference in the 'actions of marine science' dimension could have been that high school students might not be so fond of science in general, particularly given the stereotypes about learning physics and chemistry. The two groups of students were not so understanding of the practicality and future development of marine science. They thought, in other words, that learning marine science would not be helpful in their future lives. Moreover, marine science was not the main subject in the school. Therefore, the differences in their 'feelings about marine science' and the 'actions of marine science' were not significant.

There was a significant difference between the two groups for the 'cognitions regarding marine science' dimension. That is, when an external stimulus occurs, the human brain will receive a message, and this message will cause the person to respond, as described by Piaget's assimilation phenomenon. People will perceive the chemical reaction to this message in terms of their original cognitive schema. If the message is relevant, then people will pay attention and assess it, according to the received content, to produce interest or anxiety. Regardless of the situation, it will provide a short-term cognitive schema in the mind to further affect their behavior. Relatedly, the students in the experimental group might have believed that the knowledge and skills relating to marine science could be efficiently obtained in the course through the board game. Moreover, they could learn together in a way that would entail increased learning fun and practicality. Upon engaging in learning marine science, the students would be interested in the course, and then would gain in-depth understanding of the process in terms of its relevance and practicality. Not only students would the students naturally be willing to learn, but they could also absorb more knowledge. This was the reason why the 'cognitions regarding marine science' dimension had a significant difference.

The results of that research's analysis showed that the elementary school students in the middle grades had significant differences after playing the game, which was designed in light of the marine education goals. In that research, the students' interest in marine education was enhanced by the game. However, the learning interest of the high achieving students was high, while the students with average and low levels of achievement had little interest in the learning activities. It could thus be seen that the interest of each student was different even with respect to the same learning content and learning activities (Chang, Hung, & Lin, 2015). For some students, maybe different teaching methods will affect their learning interest, while other students may not be affected by the use of different teaching methods. In this study, the board game teaching method had a significant relationship with the students' interest in learning marine science. It was speculated that the board game served as a stimulating medium that was more efficient than the expository teaching method in the marine science course. Therefore, the board game teaching method had an impact on the cognition dimension of the MSLI, but no comprehensive effect on the MSLI.

For the MSLA inventory, according to Bloom revised edition, the memory is interpreted as extracting knowledge from long-term memory. In the board game teaching, the students consistently played and repeated the same activities. They would virtually memorize the concepts of marine science and then retrieved them as needed. In the control group taught with the general expository teaching method, meanwhile, the students only heard a one-way description of the concepts and did not repeat them back. Thus, the memory dimension showed significant differences between the two groups. The meaning of the understanding dimension refers to creating ideas from the teaching information and linking new knowledge with old experiences. Relatedly, the board game teaching emphasized the relationships of previously learned knowledge with the new MS concepts and the board game during the course. In contrast, the control group taught with the general expository teaching method learned some

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new MS concepts, but not repeatedly. Therefore, the understanding dimension showed a moderately significant difference with p <.01.

In the high-level thinking dimension, there was also a significant difference. That is, the experimental group had much better high-level thinking performance than the control group. This may have been because this research took the 'apply, analyse, evaluate, and create' actions collectively as the high-level thinking dimension. The high-level thinking included the 'apply' action, a proceeding to the programme; the 'analyse' action, which involves the use of procedures to solve a problem and has a close connection with procedural knowledge; the 'evaluate' action, meaning the act of looking at something according to the related criteria and standards; and the 'create' action, which involves assembling the elements together to form a complete and functional whole. In other words, high-level thinking was a cognitive process. It was the essential ability to break down, judge, and combine. When the board game was integrated into the teaching, all the central conceptual knowledge was aggregated in the board game so that the students could use the knowledge when playing. In the expository teaching method of the control group, meanwhile, the marine science knowledge could not be integrated into the MS units in the same way. Therefore, for the high-level thinking results, the students in the experimental group had better ability and showed a significant difference with the control group students.

Chan and Chang (2014) found that interactions with peers among high school students were positive for learning achievement. Moreover, the better the interactions between the students and the teacher were, the higher the students' learning achievement would be. Also, the learning skills did not have apparent influences on learning accomplishment. This research suggested that board game teaching could increase the interactions between peers and also enhanced the interactions between the teacher and the students, which had a positive effect on the learning achievement for marine science. From the above results, it can be seen that the students in the board game teaching programme did better than the students in the other programme in terms of the marine science cognitive process of learning achievement, and this was helpful for learning marine science.

For the MSPC sentences making test, the average score in the accuracy domain for the experimental group was 15.80 on the pre-test, but for the post-test, it was 33.32 points. This indicated that the accuracy was nearly doubled after the board game teaching. The depth of explanation score in the pre-test was 13.96, and it was 28.32 in the post-test. This indicated that the students made sentences of low descriptive quality for the most part. The complexity score of the pre-test was 15.52, and it was 26.16 in the post-test. That indicated that when the students were making sentences, there was a tendency to write simple sentences. The three dimensions illustrated that the level of marine science concept sentence making was raised from low to moderate. The total score was 87.80 (58.53%), and the performance was not satisfactory.

In the control group, the average score for the accuracy of the marine science concepts in the pre-test was 18.69, and in the post-test, it was 29.73 points. Although the pre-test score was higher than that of the experimental group, the post-test score was lower than that of the experimental group. The depth of explanation score in the pre-test was 14.69, and it was 26.12 in the post-test. This indicated that the students achieved descriptive quality for the most part. The complexity score of the pre-test was 15.88, and it was 24.73 in the post-test. That indicated that when the students were making sentences, there was a tendency to write simple sentences. The three dimensions illustrated that the level of marine science concept sentence making was raised from low to moderate. The total score was 80.58 (53.72%), and the performance was not satisfactory. According to the assessment results of the three dimensions, the marine science concepts of the students only reached the moderate level (Tsai & Chang, 2018; Chang, 2019; Tsai, Lin, & Chang, 2019).

Conclusions

According to the above research results, it could be found that the board game teaching method mostly had better results than the traditional expository teaching method in terms of learning motivation, learning interest, and learning achievement in marine science. The detailed explanations for this finding are as follows.

Regarding the MSLM, the relevance, confidence, and total score were significantly different between the two groups, while the two dimensions of attention and satisfaction were not significantly different. That meant that the board game teaching method was better than the expository teaching method in terms of the relevance, confidence, and total score aspects of the MSLM.

In the MSLI, the 'cognitions regarding marine science' scores were significantly different between the two groups. However, the 'feelings about marine science', 'actions of marine science', and total score were not signifi-

https://doi.org/10.33225/jbse/19.18.907

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

cantly different. It could thus be said the board game teaching method affected only the 'cognitions regarding marine science' dimension of the MSLI.

The MSLA consisted of two parts, the MSLA test and the marine science propositional concepts sentence making test. In the MSLA test, all the dimensions including memory, understanding, high-level thinking, and total score were significantly different between the two groups. Therefore, the board game teaching method had a significant influence on the MSLA results. For the marine science propositional concepts sentences, there was only a significant difference in the accuracy dimension between the two groups. However, the depth of explanation, complexity, and total score results were not significantly different. That indicated that the board game teaching method affected only the accuracy dimension of the marine science propositional concepts sentence making. In conclusion, the board game teaching method may help students to learn a greater amount of correct information during a marine science course and have some influence on their MSLA outcomes. The purpose of this research was to measure the impact of the board games teaching into marine science on the learning motivation, learning interest and learning performance of marine science in the high school. Many studies suggested that the board games could enhance the learning motivation and interest. About the board game, pointed out that many board games, which for research or teaching, often emphasize on the teaching of knowledge and ignore gameplay, making the "board game" into a "teaching tool." It would not cause the interest of students naturally.

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Received: *July 12, 2019*   Accepted: *November 30, 2019*

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https://doi.org/10.33225/jbse/19.18.907