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**Abstract.** *In recent years, marine science education has received increasing attention around the world, but the integration of STEM education into the marine curriculum is rarely applied to lower-secondary schools. The purpose of this research was to determine the effect of a teaching module on the topic of marine science, developed using a STEM approach, on the motivation, interest, and marine science achievements. The 9th-grade students from two classes in a Taiwanese public school were recruited in this study. Students in the experimental group were taught using the STEM course. Students in the control group were taught in a traditional didactic teaching course. Pre- and post-tests were used to determine marine science achievement, interest, and learning motivation. The experimental group gained significantly superior scores in three out of four dimensions towards motivation and two out of three dimensions interest. A significant difference was found between the experimental group and the control group, with the former showing increased marine science achievement over the latter in higher-order thinking; however, no significant differences were with respect to cognition. It is concluded that involving STEM-based implementations in teaching, the subject "Marine Science" increases the success rate and attitude towards the subject of students.*

**Keywords:** *learning interest, learning motivation, marine science achievement, STEM*

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## EFFECT OF A STEM-ORIENTED COURSE ON STUDENTS' MARINE SCIENCE MOTIVATION, INTEREST, AND ACHIEVEMENTS

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### Introduction

With the rapid advancement of technology worldwide, new knowledge societies are being formed. In such societies, knowledge workers are expected to be able to organise and analyse complicated knowledge and information and subsequently innovate on that basis, with the end goal being economic development. On the Partnership for 21st Century Skills website, 21st century skills, otherwise known as the 4 C's, are critical thinking, creative thinking, communication, and collaboration (Qian & Clark, 2016; Van Laar et al., 2017). Governments hope that students and other citizens relentlessly pursue high-level thinking and problem-solving skills. As such, conventional education methods must be adjusted to suit this new knowledge era.

In 1986, to promote national development and define requirements for nurturing talent, the National Science Foundation proposed a curriculum composed of science, technology, engineering, and mathematics (STEM) and focused on linking knowledge with practical situations (National Science Board Task Committee on Undergraduate Science and Engineering Education, 1986). STEM curricula are designed to integrate science, technology, engineering, and mathematics to encourage students to use technology and scientific thinking to solve problems and connect acquired knowledge to life experiences (Mohtar et al., 2019). In addition, through nurturing communication, teamwork, and practical skills; independent thinking; and the ability to innovate and create in students such curricula, to ensure students can apply related knowledge successfully upon entering the workforce.

STEM curricula focus on imparting in students the ability to adapt to rapidly changing societies and providing them with the requisite knowledge, attitude, and skills to solve real-world problems. Dabney et al. (2012) contended that interdisciplinary discussions and activities enrich STEM curricula and enhance students' learning interest (Raju & Clayson, 2010; Tindall & Hamil, 2004). Harrel (2010) considered STEM education, which involves interdisciplinary teaching, to be more suitable for instruction in natural science and perceptive topics compared with conventional teaching because solutions to the problems encountered in daily life often involve the appli-

cation of knowledge from more than one academic field. According to Dewaters and Powers (2006), students are generally satisfied with having discussions in STEM courses; such discussions enable them to resolve issues they encounter in daily life. Moreover, according to Bingölbali et al. (2007), the interdisciplinary STEM teaching process affects students profoundly, reinforcing their positive attitudes towards STEM curricula and related career choices. STEM education involves learning topics related to technology and engineering, which, according to Cunningham and Lachapelle (2016), heightens students' creativity and higher-level thinking, stimulates the integration of an entire STEM curriculum, and improves students' learning motivation and outcomes—the last being a product of interdisciplinary discussions. Moore et al. (2015) indicated that STEM education, which involves engineering-based thinking, enhances students' key 21st century skills, learning interest, and learning outcomes. Cantrell et al. (2006) reported that incorporating engineering-based thinking in a STEM curriculum improves students' scientific learning and comprehensive analytical skills. Schnittka and Bell (2011) reported that employing engineering scenarios to explain scientific concepts and knowledge reinforces students' conceptual understanding. Through a teaching experiment, Ortiz et al. (2015) demonstrated that building a Lego robot design incorporated with mathematical and engineering concepts considerably increased students' knowledge of related concepts as well as their learning retention and transfer.

Lumsden (1994) defined learning motivation as a learner's voluntary intention to learn. Learners differ in their learning behaviours and outcomes because they have unique personalities and learning goals. Although psychologists from various academic disciplines disagree about the definition of learning motivation, they agree that it relates to learning behaviours. Learning motivation comprises internal motivation (e.g., preferences, feelings, and interests) and external motivation (e.g., rewards, praise, and punishment avoidance). Keller (1987) established the attention, relevance, confidence, and satisfaction (ARCS) model, which aims to improve learning motivation. Interest and motivation are internal factors that trigger specific behaviours. Although the behaviours triggered by motivation are aimed at a specific goal, motivation does not necessarily lead to satisfaction because goals may not always be achieved. Subject-specific learning interests can be divided into those related to subject content and specific learning activities (Häussler et al., 1998). Learning motivations and interests affect learning outcomes profoundly (Fan, 2011; Pintrich, 2000; Pintrich & De Groot, 1990; Solak & Cakir, 2015; Tasgin & Coskun, 2018; Tuan et al., 2005). Studies have revealed that favourable learning motivation can improve learning efficiency, performance, and outcomes (Afzal et al., 2010; Berger & Karabenick, 2011; Ismail et al., 2010; Maliqi & Borincaj-Cruss, 2015; Pokay & Blumenfeld, 1990).

Taiwan is surrounded by ocean and possesses abundant ocean resources. However, pollution of ocean waters and the severity of ocean-related environmental problems have continued to increase. Inappropriate handling of oceanic resources and helplessness in the face of marine disasters indicate that Taiwanese citizens have generally received insufficient ocean education (Chang, 2015; Tsai et al., 2019). In the face of globalisation, the supply of talent for ocean-related industries does not meet the demand, a problem which is exacerbated by students having low willingness to seek occupations in marine industries. Therefore, the Taiwanese government has increasingly focused on ocean education in recent years under an aggressive policy to quickly nurture ocean-related talents who can contribute to national development (Ministry of Education, 2017). This study focused on applying STEM education to ocean-related curricula and to highlighting the problem of marine debris (trash in the ocean). The objective was to help students explore marine science in an interdisciplinary manner, collect and analyse scientific data, and use technology and engineering design techniques to support their thinking and actions. As an outcome, students were expected to be able to create devices that solve or mitigate the problem of marine debris.

### *Research Aim and Questions*

The purpose of this research was to determine how incorporating STEM education into marine science education would affect the learning motivation, interest, and achievement of lower-secondary schools students. The following research goals were proposed:

1. To explore the effects of a STEM-oriented marine science course on the learning motivation of junior high school students.
2. To explore the effects of a STEM-oriented marine science course on the learning interest of junior high school students.
3. To explore the effects of a STEM-oriented marine science course on the learning achievement of junior high school students.



## Research Methodology

### *Research Design*

One experimental group and one control group were used. The experimental group received teaching in a STEM-oriented marine science course, whereas the control group received teaching in employing didactic teaching. Because of class size restrictions imposed to maintain normal classroom operations during the semester, random sampling of participants and strict control of experimental scenarios were not possible. Purposive sampling was used to select two classes, with one to serve as the experimental group and the other as the control group. The experimental group received STEM course teaching that integrated beliefs, principles, and methods related to STEM into marine science, with a focus on marine debris (National Science Board Task Committee on Undergraduate Science and Engineering Education, 1986; Qian & Clark, 2016; Van Laar et al., 2017). The control group students received conventional didactic teaching. The study period was 6 weeks; two classes were held each week from February to April 2018. The students underwent Pre-test that assessed their learning motivation, interests, and achievements. Immediately after the end of the course, the same three topics were evaluated through a Post-test.

### *Participants*

The participants were 9th-grade students from two classes at a public lower-secondary school in Taiwan. Upon entering lower-secondary school (seventh grade), these students were placed in classes according to their academic level through the spiral arrangement method; for this reason, their academic levels were approximately equivalent. The experimental group consisted of 20 students (9 boys and 11 girls), and the control group consisted of 27 students (13 boys and 14 girls). All the students were approximately 16 years old. The two groups of participating students first filled out a consent form to indicate their agreement to take part in this research, after which they then completed the questionnaires anonymously.

### *Education Approach*

#### *STEM Course*

Biweekly classes were held for 6 weeks (12 classes in total), and each class lasted 45 minutes. Through questions, answers, discussions, and exercises, educators guided students to develop good communication skills and to use their acquired knowledge to solve problems and complete hands-on learning activities. The planned education process is presented in Table 1.

**Table 1**  
*Learning Progress in the STEM-Oriented Marine Science Course*

Week	Segment	Activities
1	The importance of the ocean	
2	Ocean currents and circulation	Ocean current simulation experiment
3	Trash in the ocean	
4	Trash belts in the ocean	
5	The effects of trash on ocean ecosystems	
6	Protecting the ocean and removing ocean trash	Creation of an ocean vacuum cleaner

The curriculum was based on the perspective of Trowbridge and Bybee (1990) and the 5E (engage, explore, explain, elaborate, and evaluate) instructional model they proposed in the Biological Science Curriculum Study. The aim of using this teaching strategy was to design educational content that can help students develop their spirit of exploration. The learning activities in this study encompassed, for example, the topics of scientific principles and



the use of technology, engineering design, mathematical statistics, and chart analysis. The aim of the integrated STEM-oriented curriculum was to consolidate scientific knowledge and skills through hands-on activities so that students could apply scientific knowledge to real-life problem solving. Each STEM component is presented in Table 2.

**Table 2**

*STEM Knowledge Analysis and Assessment for the Marine Science Curriculum*

Subject	Teaching concepts
Science ( S )	<ol style="list-style-type: none"> <li>1. Water circulation</li> <li>2. Oceans and climate adjustments</li> <li>3. Ocean currents, planetary wind systems, circulation, and wind speeds</li> <li>4. Material decomposition</li> <li>5. Buoyancy</li> <li>6. Types and sources of ocean trash</li> <li>7. Understanding the effects of ocean trash decomposition</li> <li>8. Biomagnification</li> <li>9. Discussing methods for reducing plastic product usage and preventing waste from becoming ocean trash</li> <li>10. Writing down the thinking process and explaining it (scientific method)</li> <li>11. Principles of an ocean trash cleaning device</li> </ol>
Technology ( T )	<ol style="list-style-type: none"> <li>1. Principles of ocean current power generation, tidal power generation, and energy development</li> <li>2. Designing an experiment</li> <li>3. Designing a project that solves a problem</li> <li>4. Designing and simulating a small-scale ocean current model</li> <li>5. Learning about plastic waste treatment methods</li> <li>6. Designing a device for removing ocean trash</li> </ol>
Engineering ( E )	<ol style="list-style-type: none"> <li>1. Processes of ocean current power generation, tidal power generation, and energy development</li> <li>2. Creating a device</li> <li>3. Thinking of strategies for preventing or removing ocean trash</li> <li>4. Creating a device for removing ocean trash</li> </ol>
Math ( M )	<ol style="list-style-type: none"> <li>1. Calculating the amount and volume of ocean trash</li> <li>2. Collecting and analysing data</li> <li>3. Presenting data in charts and graphs and explaining the results</li> <li>4. Converting data into percentages and explaining them</li> <li>5. Creating an easy-to-understand presentation of data by using a chart</li> </ol>

### *Didactic Teaching Course*

The didactic teaching course in this research was prepared by researchers and contained identical conditions to those of the STEM course in terms of science content, teaching materials, and pace of teaching. This 6-week course (12 classes, 45 minutes each) was based on group learning. The teaching materials given to students and the education progress markers were identical to those in the experimental group. The content of the course is presented as in Table 1, but no activities are included. This group is teacher-centred, with students sitting quietly and listening attentively, only passively accepting the teacher's efforts to convey the marine science knowledge in Table 1.

### *Instruments*

The instruments used in this study included a marine science learning motivation scale, a marine science learning interest scale, and a marine science learning achievement test.



### Marine Science Learning Motivation Scale

Keller's ARCS model (Keller, 1987) was the foundation for developing this study's learning motivation scale. For this 5-point Likert-type scale, students could select one option for each question (*strongly agree, agree, neither agree nor disagree, disagree, or strongly disagree*). The scale had four subscales, namely attention, relevance, confidence, and satisfaction, and 16 questions in total were asked (Lin et al., 2019). Although Lin et al. (2019) demonstrated that this scale has good reliability and validity, its internal consistency and construct validity were again verified in this study.

Cronbach's  $\alpha$  was used to measure the internal consistency of the scale and subscales. The  $\alpha$  values for attention, relevance, confidence, and satisfaction were respectively .96, .93, .92, and .96, and the total scale score was .98. All values were above .9. The confirmatory factor analysis (CFA) results are presented in Table 3. The subscale of emotional reactions towards the ocean contained three items. It had an average variance extracted of .78 and component reliability of .91. The acknowledgement of marine science's importance subscale contained four items, and it had an average variance extracted of .82 and component reliability of .95. The actions taken to learn marine science subscale contained four items (average variance extracted: .75, component reliability: .92). The average variance extracted values of these three subscales satisfied the requirement that they be  $>.5$ . Moreover, the three subscales had favourable component reliability scores. The learning motivation and learning interest scales thus had appropriate internal consistency and construct validity.

### Marine Science Learning Interest Scale

Marine science learning interest was assessed using a 5-point Likert-type scale (*strongly agree, agree, neither agree nor disagree, disagree, or strongly disagree*). The scale had three subscales, namely emotional reactions towards the ocean, acknowledgement of marine science's importance, and actions taken to learn marine science; 11 questions were asked (Lin et al., 2019). The marine science learning interest and marine science learning motivation scales were both reviewed by four experts to evaluate their content validity and remove unsuitable questions. These scales were pretested together before educational instruction commenced. The Pre-test was administered by test administration committee members, all of whom had undergone standardised test training.

CFA was used to evaluate the construct validity of the scales. The results are presented in Table 3. The attention subscale of the marine science learning motivation scale contained five items (average variance extracted: .82, component reliability: .96). The relevance subscale contained three items (average variance extracted: .82, component reliability: .93). The confidence subscale contained three items (average variance extracted: .80, component reliability: .92). The satisfaction subscale contained five items (average variance extracted: .83, component reliability: .96). The average variance extracted values of all the four subscales satisfied the requirement that they be  $>.5$ . Moreover, the four subscales had good component reliability scores. Generally, a component reliability above .6 is considered appropriate and a reliability above .5 is acceptable (Bagozzi & Yi, 1988; Diamantopoulos & Siguaw, 2000; Kline, 1998).

**Table 3**

*Research Variables and Subscales as Well as Average Variance Extracted and Component Reliability Values*

Variables	Subscale	Number of items	Variance extracted	Component reliability
Marine science learning motivation	Attention	5	.82	.96
	Relevance	3	.82	.93
	Confidence	3	.80	.92
	Satisfaction	5	.83	.96
Marine science learning interest	Emotional feeling toward the ocean	3	.78	.91
	Acknowledgment of marine science	4	.83	.95
	Actions taken toward marine science	4	.75	.92



### Marine Science Learning Achievement Test

The marine science learning achievement test consisted of 15 single-choice items. The cognitive processes of memory (four items), understanding (four items), and higher-level thinking (seven items) were analysed. To ensure the test had content validity, it was designed by the authors and three marine science experts, who were also secondary school teachers. The measurement framework for this test was based on ocean literacy and knowledge, especially the seven basic principles of ocean literacy set forth by the National Marine Educators Association (NMEA, 2010) and National Oceanic and Atmospheric Administration (NOAA, 2013). The seven basic principles of ocean literacy are as follows: (1) The Earth has one large ocean with numerous features; (2) the ocean and ocean life shape the features of the Earth; (3) the ocean has a major influence on weather and climate; (4) the ocean makes the Earth habitable; (5) the ocean supports diverse life and ecosystems; (6) the ocean and humans are inextricably interconnected; and (7) the ocean is largely unexplored (NMEA, 2010).

The Pre-test and Post-test results for the learning achievement test in the current study were analysed using the Kuder–Richardson Formula 20 (KR-20). The KR-20 estimates reliability according to the consistency of all items. The KR-20 results for the pilot study, Pre-test, and Post-test were .67, .62, and .66, respectively, indicating that this instrument had appropriate internal consistency.

### Statistical Analyses

Cronbach's  $\alpha$  and CFA were employed to evaluate the reliability and construct validity of the instruments. Mean and standard deviation were used to describe learning motivation, interest, and achievement. A one-way analysis of covariance (ANCOVA) was used to evaluate differences between the pre-test and post-test scores for learning motivation, interest, and achievement.

## Research Results

### Comparison of Learning Motivation Between Groups

Descriptive statistics for the learning motivation of students in the experimental and control groups before and after marine science course instruction are presented in Table 4. The results in Table 4 indicate that the experimental group attained higher scores than the control group for all subscales and the total test.

**Table 4**  
Descriptive Statistics for Learning Motivation, Interest, and Achievement

Scales	Number of items	Group	Pre-test		Post-test	
			<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Attention	5	Experimental	15.75	2.34	18.85	2.87
		Control	15.48	3.72	17.52	4.77
Relevance	3	Experimental	13.00	2.10	15.10	2.13
		Control	11.56	4.10	13.96	3.40
Learning Motivation	3	Experimental	10.95	1.61	12.05	1.61
		Control	9.52	3.43	10.85	2.93
Satisfaction	5	Experimental	15.05	3.50	17.35	3.45
		Control	14.11	5.66	15.93	4.90
Total score	16	Experimental	54.75	7.99	63.35	7.96
		Control	50.67	15.70	58.26	14.90



Scales	Number of items	Group	Pre-test		Post-test		
			M	SD	M	SD	
Learning Interest	Emotional feeling toward ocean	3	Experimental	9.90	1.62	10.3	1.53
		Control	9.48	2.49	9.81	1.82	
	Acknowledgment of marine science	4	Experimental	13.95	2.74	15.5	2.33
		Control	12.59	4.37	14.07	3.46	
	Actions taken toward marine science	4	Experimental	13.05	2.74	13.95	2.24
		Control	11.30	3.88	13.15	3.11	
Total score	11	Experimental	36.90	5.03	39.75	4.54	
Control	33.37	10.20	37.04	7.30			
Achievement	Memory	4	Experimental	3.10	.96	3.20	1.06
		Control	2.19	1.18	3.37	.97	
	Understanding	4	Experimental	2.85	1.09	2.90	.72
		Control	2.37	.88	3.07	.92	
	Higher-level	7	Experimental	4.40	1.64	4.80	1.65
		Control	3.74	1.87	3.59	1.85	
Total score	15	Experimental	10.35	2.82	10.90	2.83	
Control	8.30	2.77	10.04	2.65			

To compare learning motivation scores between experimental and control groups, a one-way ANCOVA was conducted for data analysis; the results are presented in Table 5. A significant difference ( $F = 4.22, p = .046$  [ $<.05$ ]) in attention scores was observed between the experimental and control groups. A significant difference was also identified in relevance ( $F = 5.77, p = .021$  [ $<.05$ ]) and satisfaction ( $F = 5.77, p = .021$  [ $<.05$ ]) scores. The total scores were also significantly different between the groups ( $F = 5.87, p = .020$  [ $<.05$ ]). The results indicated that the experimental group significantly outperformed the control group in attention, relevance, satisfaction, and total scores. This indicated that the STEM-oriented marine science course for lower-secondary school students positively affected their learning motivation.

**Table 5**  
ANCOVA Results for Learning Motivation, Interest, and Achievement

Scales	Source	Type III sum of square	df	Average sum of square	F	p
Attention	Between	82.26	1	82.26	4.22	.046*
	Within	858.55	44	19.51		
Relevance	Between	55.09	1	55.09	5.77	.021*
	Within	420.03	44	9.55		
Confidence	Between	25.02	1	25.02	3.75	.059
	Within	293.39	44	6.67		
Satisfaction	Between	128.11	1	128.11	5.77	.021*
	Within	977.24	44	22.21		
Total score	Between	1140.39	1	1140.39	5.87	.020*
	Within	8545.90	44	194.23		



	Scales	Source	Type III sum of square	df	Average sum of square	F	p
Learning interest	Emotional feeling toward marine science	Between	31.18	1	31.18	7.43	.009**
		Within	184.52	44	4.19		
	Acknowledgment of marine science	Between	48.52	1	48.52	4.71	.035*
		Within	453.13	44	10.30		
	Actions taken toward marine science	Between	34.94	1	34.94	3.71	.061
		Within	414.97	44	9.43		
Total score	Between	339.31	1	339.31	6.32	.016*	
	Within	2362.46	44	53.69			
Achievement	Memory	Between	.31	1	.31	.32	.576
		Within	43.25	44	.98		
	Understanding	Between	.14	1	.14	.19	.663
		Within	31.04	44	.71		
	Higher-level	Between	35.77	1	35.77	10.82	.002**
		Within	145.41	44	3.31		
Total score	Between	33.88	1	33.88	4.32	.044*	
	Within	345.22	44	7.85			

\* $p < .05$ , \*\* $p < .01$ , \*\*\* $p < .001$ .

The results indicated that with respect to total scores, the effect of the STEM-oriented course on high school student's motivation to learn marine science was significant. For the learning motivation scale, a significant between-group difference was observed in attention subscale scores. Those taking the STEM-oriented course believed that marine science courses are highly attractive, possibly because in STEM education, real-life scenarios are often simulated that force students to think independently and conduct group discussions, resulting in increased opportunities for hands-on learning. Such opportunities can increase student engagement.

#### *Comparison of Learning Interest Between Groups*

The results in Table 4 indicate that the experimental group scored higher than the control group in the subscales of emotional reactions towards the ocean, acknowledgement of marine science's importance, and the actions taken to learn towards advancing marine science in the learning interest pre-test and post-test. The experimental group also attained a higher total score than that of the control group.

The one-way ANCOVA results are presented in Table 5, and they indicate a significant difference in learning interest between groups with respect to emotional reactions towards the ocean ( $F = 7.43, p = .009 < .01$ ) and acknowledgement of marine science's importance ( $F = 4.71, p = .035 < .05$ ). Actions taken to learn marine science subscale scores were not significantly different ( $F = 3.71, p = .061 > .05$ ) between the groups. The total score was significantly different ( $F = 6.32, p = .016 < .05$ ) between the groups. The experimental group outperformed the control group in the emotional reactions towards marine science, acknowledgement of marine science's importance and total scores, implying that the STEM-oriented marine science course had positive effects on the learning interest of students.

The effect of the STEM-oriented course on the total score for learning interest was significant. Incorporating the engineering thinking component of STEM into education is beneficial for students' development of key 21st century skills and can improve their interest and achievement in STEM fields.

Significant differences were noted between student group scores in the emotional reactions towards marine science subscale. Scores of the STEM-oriented education group revealed a significantly increased enjoyment of and interest in marine science. STEM education may have led to these increases through the incorporation of knowledge and skills required in daily life into the curriculum. Therefore, these students did not view marine science irrelevant or boring. Through hands-on activities, students came to understand that they could contribute to protecting the ocean through their actions.



With respect to acknowledging marine science's importance, significant differences were observed between the groups. Students in the STEM education group believed they could effectively obtain knowledge and skills related to marine science from the curriculum. STEM education emphasises interdisciplinary curricula and grounding coursework in daily life situations to demonstrate the practical value of course content. Problems encountered in daily life are often relevant to two or more disciplines. If education is strictly siloed in disciplines, students may encounter difficulty learning and ultimately lose interest in a course. The interdisciplinary nature of STEM education can help students overcome such difficulties. STEM education is especially appropriate for education related to natural sciences and the sensory world. When education has an entertaining approach, students can be guided to develop an interest in their courses and may acquire an in-depth understanding of the relevance and practicality of the material. Subsequently, they may have an increased willingness to learn and ability to absorb more knowledge. Compared with the didactic teaching course group, the STEM education group demonstrated greater marine science learning interest with respect to emotional reactions towards marine science and acknowledgement of marine science's importance. If educators can guide students to engage in learning not strictly oriented to test-taking and increase their interest in marine science, more students may experience sustained, autonomous learning of marine science, which may increase their marine science-related activities.

#### *Comparison of Learning Achievement Between Groups*

The results in Table 4 indicate that the experimental group had higher scores in all subscales (memory, understanding, and higher-level orientation) and a higher total score than that of the control group. The one-way ANCOVA results are presented in Table 5, and they indicate no significance between-group differences in memory ( $F = 0.32, p = .576 [>.05]$ ) and understanding ( $F = 0.19, p = .663 [>.05]$ ). However, the experimental group obtained higher scores for higher-level orientation ( $F = 10.82, p = .002 [<.01]$ ) and higher total scores ( $F = 4.32, p = .044 [<.05]$ ) than did the control group.

#### **Discussion**

The main aim of this research was to determine the effect of incorporating STEM aspects into marine science education on the learning motivation, interest, and performance of lower-secondary school students. With respect to learning motivation, students in the STEM education group scored better in attention, relevance, and satisfaction than did the control students. Confidence was the only subscale in which significant differences were not evident. Students in the STEM education group may not have been familiar with the tools used or lacked the confidence required to devise possible approaches. Skills learning was not reflected in the test scores. Therefore, no increase in confidence was observed in the learning motivation of students in the STEM education group. If students undergo long-term development that results in having the confidence to express their thoughts and propose ideas, and if they can be given the opportunity to familiarise themselves with related tools, they may develop a high level of confidence in their execution ability. Therefore, teachers seeking to increase students' marine science learning motivation should consider incorporating STEM education into their teaching approach.

This result agrees with the conclusion of Cunningham and Lachapelle (2016). Gaining learning experiences related to technology and engineering promotes creativity and higher-level thinking and can encourage the consolidation of STEM subjects. In interdisciplinary discussion scenarios, such an approach can also improve learning motivation and performance (Cunningham & Lachapelle, 2016). In student views on marine science's relevance, significant between-group differences were observed. Compared with the students in the control group, the students in the STEM education group had a stronger belief that marine science was highly relevant to them. STEM education emphasises connecting knowledge and real life through the incorporation of current events and real-life examples into a curriculum. Students can identify problems and propose relevant solutions. This finding accords with the conclusion of Dewaters and Powers (2006). In their study, students were satisfied with interdisciplinary discussion of STEM themes and believed that their courses and experiences were beneficial for solving problems encountered in daily life (Dewaters & Powers, 2006). With respect to course satisfaction, the groups exhibited significant differences. Students in the STEM education group stated that the marine science curriculum gave them a greater sense of achievement. STEM education guides students to first identify problems and then design and manufacture products that can solve these problems. Students are engaged throughout the process, and the tangible finished products can give students a sense of accomplishment. Therefore, students in the STEM education



group had greater satisfaction with their course than the control group had with theirs.

The STEM education group scored higher than the control group did in two learning interest subscales, namely emotional reactions towards marine science and acknowledgement of marine science's importance. However, no significant difference was observed in the actions taken to learn marine science subscale. Possible reasons for this result are that both groups of students did not have an in-depth understanding of the practical utility of their marine science education and future marine science developments, or that they held certain preconceptions and believed that such an education would not benefit them in the future. Furthermore, marine science is not a primary test subject in Taiwan. Therefore, as neither group would be tested on the subject (and thus, neither group perceived a benefit in continued study), the scores related to actions to continue the pursuit of knowledge and skills related to marine science were not significantly different between the two groups of students. Overall, the effect of STEM education on students' learning interest in marine science courses was superior to that of the didactic teaching course. Therefore, instructors who hope to increase learning interest in marine science should consider incorporating STEM education into related curricula. This recommendation concurs with those of Dabney et al. (2012), Raju and Clayson (2010), and Tindall and Hamil (2004). When students participate in STEM learning, interdisciplinary discussions and learning activities give STEM themes greater meaning and increase students' learning interest in STEM fields.

Regarding learning achievement, students in the STEM education group had higher scores than did control group students in higher-level orientation; however, no significant differences were observed in memory and understanding. The didactic teaching course group had superior performance to the STEM group in higher-level orientation, possibly because STEM education involves using exploratory teaching methods to stimulate student thinking as well as using hands-on activities to link life experiences to learning and increase students' evaluation ability. The results indicated that after STEM education was incorporated into teaching, its effect on the learning achievement of junior high school students was significant, as indicated by total scores. These findings accord with those of Cunningham and Lachappelle (2016), English (2015), and Moundridou and Kaniglonou (2008). The results for higher-level learning achievement (including application, analysis, combination, and evaluation) between groups were significantly different. This result is in agreement with that of Cunningham and Lachappelle (2016), who posited that participation in learning activities related to technology and engineering promotes creativity and higher-level thinking.

## Conclusions and Implications

The purpose of this research was to determine the effect of a teaching module on the topic of marine science, developed using a STEM approach, on the motivation, interest, and marine science achievements. With respect to learning motivation, students in the STEM education group scored better in attention, relevance, and satisfaction than did the control students. The STEM education group also scored higher than the control group did in emotional reactions towards marine science and acknowledgement of marine science's importance subscales of learning interest. Regarding learning achievement, students in the STEM education group had higher scores than did control group students in higher-level orientation.

From the conclusions of this research, some suggestions can be provided for further educational curriculum. For learning motivation, students in the STEM education group scored higher in attention, relevance, and satisfaction than did students in the control group. The confidence subscale was the only one in which significant differences were not observed. Possibly, students in the STEM education group were not familiar with related tools or lacked the confidence required to express their ideas and propose solutions. In addition, they may have felt that the skills they learned would not be reflected in test scores. Therefore, in terms of learning motivation, students in the STEM education group had no increase in confidence. Instructors who hope to increase the learning motivation of students with respect to marine science should consider incorporating STEM education into their teaching approaches.

For learning interest, students in the STEM education group scored higher than did the control students on two subscales, namely emotional reactions towards marine science and acknowledgement of marine science's importance. Possibly, both student groups did not have an in-depth understanding of the practical use of their marine science education and how they might develop marine science knowledge. Furthermore, they may have held preconceptions and believed that a marine science education would not benefit their future lives. Overall, teachers who hope to increase learning interest in marine science should consider incorporating STEM education into such curricula.



With respect to learning achievement, students in the STEM education group scored higher than did the control students in higher-level orientation. This may have been because STEM educators use exploratory teaching methods to stimulate student thinking and use hands-on activities to link learning to relevant life experiences and increase the evaluation ability of students.

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