

Article

Trans-Disciplinary Education for Sustainable Marine and Coastal Management: A Case Study in Taiwan

Hsiao-Chien Lee ¹, Kuo-Huan Ting ², Yi Chang ³, Meng-Tsung Lee ⁴ and Wen-Hong Liu ^{2,*}

¹ Foreign Languages Education Center, National Kaohsiung Marine University, Kaohsiung 81157, Taiwan; marianlee@mail.nkmu.edu.tw

² Institute of Marine Affair and Business Management, National Kaohsiung Marine University, Kaohsiung 81157, Taiwan; dgh0809@gmail.com

³ Institute of Ocean Technology and Marine Affair, National Cheng Kung University, Tainan 70101, Taiwan; yichang@mail.ncku.edu.tw

⁴ Department of Marine Leisure Management, National Kaohsiung Marine University, Kaohsiung 81157, Taiwan; masonlee@webmail.nkmu.edu.tw

* Correspondence: andersonliu@webmail.nkmu.edu.tw; Tel.: +886-7-361-7141 (ext. 3528); Fax: +886-7-364-2297

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Abstract: The present study aims to investigate the effect of a trans-disciplinary design of curricula, deemed a powerful tool for teaching and research on complex environmental problems, with a goal to help solve the real problems that climate change has brought to the coastal environment in Taiwan. Three major real-life problems in southern Taiwan—declining mullet fisheries, flooding, and coral bleaching—were integrated into four courses. Adopting a qualitative case study method, the researchers investigated the student perceptions of the trans-disciplinary learning experiences, their attitudes toward marine and coastal environmental protection, and their capability of solving the problems related to marine and coastal environments. The researchers employed various methods to analyze the student reflection reports, student self-evaluation forms, and the tape-recorded class meetings. The findings suggest the following: the trans-disciplinary curriculum stands to be an innovative yet indispensable design for coastal management education; such a curriculum benefits students by equipping them with essential knowledge and skills to succeed in future marine conservation; action learning for marine and coastal sustainability serves as the final goal of trans-disciplinary learning project; a trans-disciplinary case study on the design of curricula provides effective knowledge integration of marine and coastal sustainability.

Keywords: trans-disciplinary; coastal management; climate change; case study

1. Introduction

The coastal management system can be thought of as a system of relationships among people, policy makers and managers, and members of the scientific community [1]. “Integration” is commonly understood as one aspect of the interdisciplinary integration of scientific and other knowledge, yet without discussing in detail the forms and processes of knowledge integration [1,2]. However, knowledge integration is defined as a function of dialogic, collaborative and deliberative processes, and reflects the blending of knowledge and power aspects in the processes of knowledge use in recent works on environmental management [3–5], where less disciplinary but more thematic problems and practice-oriented perspectives of knowledge use and integration can be found [5,6].

Before climate change emerged as an academic focus in coastal research, vulnerability as such was not an important concept. Traditional research in coastal zones is conducted mainly by geologists, ecologists and engineers [7]. Vulnerability is a complex and multidimensional social space defined by

the determinate political, economic and institutional capabilities of people in specific places at specific times [8]. Climate change will significantly affect the economic, social, and environmental dimensions of sustainable development, as well as key issues like poverty and equity.

Because disciplinary research is not able to cope with many of the increasing multi-dimensional problems caused by climate change, scholars have promoted the adoption of a trans-disciplinary approach, which, as is believed, would allow researchers to solve problems that could not be solved by isolated efforts [9,10]. The trans-disciplinary approach is considered essential to deal with large-scale, long-term, complex, and interlinked issues like sustainable development and climate change [9], and will move beyond looking for one correct solution and, instead, integrate different solutions, viewpoints, or perspectives [11]. In addition, it will involve intense interaction among academics and practitioners in order to promote a mutual learning process [12,13]. Dass has called such a process an organic manner, rather than fragmented manner, for solving real-life issues [14].

Four criteria for trans-disciplinary research have been proposed: (1) Research questions are derived from real-world problems; (2) There are suitable definitions of sub-problems; (3) There is a free choice of scientific methods adequate for each of the sub-problems; (4) There are close relations between the sub-problems [15]. Therefore, trans-disciplinary research is considered as an applied practice, evolving from current, real world problems needing to be practically solved [16]. If successfully employed, the process of trans-disciplinary research will result in joint problem-solution across the sciences, technology and society [17,18]. In addition, a revised model of the problem-based learning (PBL) pedagogical approach—which supports trans-disciplinarity and is embedded with a focus on learning experiences organized around the investigation, explanation, and resolution of meaning problems [19,20]—appears appropriate to be integrated into the curricula design for environmental programs. In view of the fact that marine and coastal environmental problems involve many aspects, including marine environmental engineering and change, ocean humanities and industries, and marine policies, the present study aims to investigate the effect of a trans-disciplinary design of curricula, deemed a powerful tool for teaching and research on complex environmental problems [12], whose goal is to help solve the real problems that climate change has brought to the coastal environment in Taiwan. Three research questions have been brought up:

- What are the student perceptions of the trans-disciplinary learning experiences?
- What are the changes, if any, in the students' attitudes toward marine and coastal environmental protection?
- How do the students display the capability of solving the problems related to marine and coastal environments?

During the longitude year-long project implementation, a triangulation of qualitative data sources was conducted, including individual student reflection reports, the student self-evaluation forms, and researchers' observation notes on the video-taped class meetings. The research team employed various methods, such as the constant comparative method [21], a descriptive analysis, and the participant observation method [22,23] to analyze the data. Results gained from the study helped the research team to make pedagogical and research suggestions at the end of the article.

2. The Problems Taiwan Is Facing under the Influence of Climate Change

Climate change has become, in the past few years, the most challenging worldwide issue [24]. Coastal areas are particularly susceptible to the detrimental influence of extreme weather conditions and natural disasters, which have resulted in severe losses and damage worldwide [25]. Such effects not only undermine the productivity of ecosystems in coastal wetlands, estuaries and bays, and the oceanic physical environment, but also bring about problems such as the loss of livelihood of coastal residents, food shortages and hindering to sustainable coastal development. Therefore, climate change and the relevant risks have become one major concern of the general population, as is the urgency of understanding how to mitigate and eventually cope with it [26].

The frequent and intense use of the coastal areas in Taiwan, and the concentration of the population in the coastal plain area that takes up about 25% of the total area of the Taiwan Island, have both contributed to the high probability of environmental disasters in the coastal area. Hence, the majority of the Taiwanese cities are exposed to the negative impact of climate change, as is discussed below.

2.1. Declining Mullet Fisheries

Sea water temperature (SST) rise and acidification caused by climate change have led to the relocation of fisheries in Taiwan coastal areas. It is well recognized that striking correlations exist between climate change and the catch of mullet [27–29], for example, with the peak in 1980 at 2.53 million and then gradually decreasing, to 0.16 million in 1999. Lan et al. [30] further indicated that the decrease of grey mullet catches after 1980s was majorly influenced by the SST which increased 1.01 °C in the Taiwan Strait during the period from 1984 to 2009. They also suggested that the Pacific Decadal Oscillation and El Niño events resulted in the change of migrating behavior of grey mullet. The large scale of climate variation could trigger the more northward reach of warm water (>20 °C) in the Taiwan Strait, and fishing grounds of grey mullet would therefore shifted to the northwest water of Taiwan. Consequently, food shortages could occur, transferring Taiwan into import-reliant state [31] and changing the socioeconomic structures of fishing villages in southern Taiwan.

2.2. Flood

For the Taiwan coastal areas, floods are the most obvious and frequent disaster caused by climate change. The five major western coast cities of Taiwan are characterized by their adjacency to the sea, the low-lying terrain and the confluence of various rivers [32]. Certain geographical characteristics of these areas have resulted in only 20% of the total runoff volume being utilized, resulting in increased flooding and other damages [33]. Residents of the southwestern coast thus have been recognized as the first climate refugees, who suffer from frequent floods due to the persisting subsidence as a negative effect of climate change [34]. In order to implement sustainable development for the coastal area, the Coastal Zone Management Act (CZMA) of Taiwan was adopted in February 2015. It is emphasized that coastal protection plans shall be formulated for coastal zones for erosion, tide overflow, storm surge flooding, land subsidence, or other potential disasters by the central or local government. Therefore, shoreline protection policies/plans for fragile coasts should be adopted with approaches considering the sea levels rise driven by anthropogenic climate change.

2.3. Coral Bleaching

Near shore coral reefs are also at risk of bleaching or dying, as the surplus of heavy rain and typhoon would cause more landslides, discharging the mudflow into the sea and resulting in turbidity and eutrophication. Such changes are a threat to national security, the livelihood of residents, tourism and sightseeing, ecosystem preservation and sustainable development of fishery [35]. In addition, warm water temperatures related to climate change is well documented to increase the rate of coral bleaching [36]. On the contrary, extremely cold water event occurring in the winter of 2008 have also been observed to cause bleaching in coral reefs around the Penghu Islands, southern Taiwan Strait, wreaking havoc on marine resources and on the coral reef ecosystem [37]. Fisheries and coastal managements should therefore include adaptation strategies responding to the climatic influences on marine ecosystems and fisheries.

3. Design of the Curricula

The 1992 United Nations Conference on Environment and Development emphasized that nations should consider building an integrated management system of all the natural resources and their sustainable development. Therefore, in order to cope with the marine and coastal environmental issues resulting from climate change, the researchers, as teachers at a Taiwanese university, whose focus has been educating marine professionals, find it necessary to educate students to become individuals

with the minds and capabilities to discover, care about, and solve problems, especially those related to the current marine and coastal environmental ones. Because all these require a soundly developed educational program, the trans-disciplinary research and teaching team created a year-long project, consisting of four courses in total, with each closely related to each other in terms of course goals, designs, and pedagogical practices.

The design of the curricula was based on the principles that class instructions moved from the basics to the advanced and combined the theories with the practical, while solving real-life problems remained the ultimate goal. The four courses, namely, *Marine Policy*, *Marine Environmental Science*, *Ocean Literature*, and *Marine and Coastal Environmental Education Communication*, were taught throughout two semesters, each lasting 18 weeks. Each course was taught simultaneously by two instructors from various academic backgrounds, while lectures by experts and stakeholders were given throughout the project. The first three courses, carried out in the first semester, emphasized the development of student knowledge, skills, and attitudes. The last course, *Marine and Coastal Environmental Education Communication*, implemented in the second semester, aimed to provide the students with a practical application of what they had learned. Each individual course required the students to meet once a week, lasting two hours each time. In addition, extra field trips were conducted across courses. In other words, students taking the three courses in the first semester, along with their instructors, went to places where the people faced the real problems caused by the climate change to observe and to discuss with local experts and scholars. For example, they went on fieldwork to find out more about the declining mullet fishery in Shin Da Port, flooding in Linbian Township, and coral bleaching in Kenting. Then in the fourth course, the students integrated what they had learned and cultivated into educational workshops they created for school children. In this way, the students put what they gained from the project into action.

Therefore, a revised model of the problem-based learning (PBL) approach was adopted as the main instructional method. Without necessarily following every PBL step, the teaching-research team encouraged the students to learn by solving real-life problems. The following Figure 1 shows the inter-connection of the four courses and a detailed introduction is provided below.

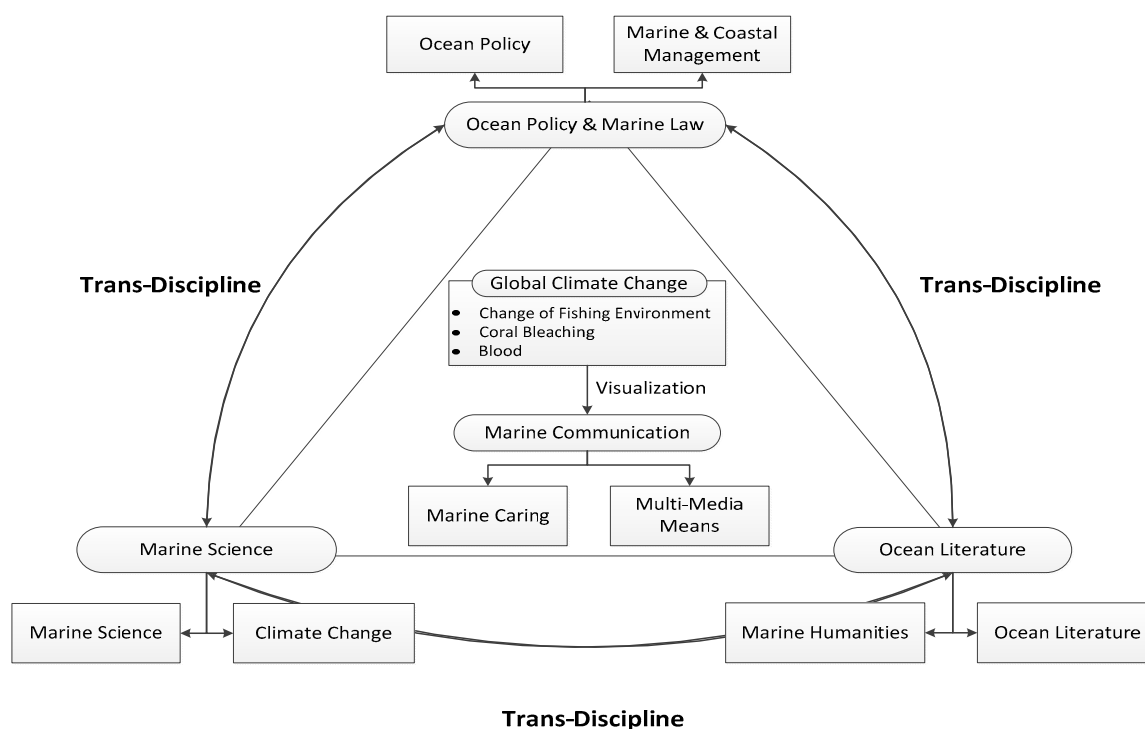


Figure 1. Summary of the inter-connection of the courses.

3.1. “Marine Policy” Course

The main purpose of the course, *Marine Policy*, was to discuss the issues concerning marine policy, introducing systematically the adaption to climate change and discussing the disputes over the key scientific facts of climate change. It aimed to cultivate student scientific literacy, encouraged them to re-examine the multiple aspects among humans and the environment, and ultimately helped them develop skills and capabilities for civic participation. Because scientific background knowledge was essential when the students prepared their final project, this course was closely integrated with another course, *Marine Environmental Science*. The introduction of ocean remote sensing and geographic information systems were given in the course. In addition, the understanding of marine environments for stakeholders including fishermen and government authorities is crucial for marine management systems. Two case studies were discussed in detail to elaborate how the application of scientific analysis improved the decision-making for fisheries management [37] and marine protected areas [38]. The given lecture should provide a clear vision of cross-sectors of both societal issues and scientific data to improve the decision making of marine policy.

3.2. “Marine Environmental Science” Course

The course, *Marine Environmental Science*, provided the scientific background for the course, *Marine Policy*. Basic marine knowledge, marine environmental change, and marine environmental management were all taught. Through group discussion, peer collaboration and evaluation, and group oral presentations, the course aimed to cultivate the four core competences: language and communication competence, problem detecting and solving competence, technology competence, and multi-cultural competence. Moreover, students were required to operate the analysis of satellite-derived SST and ocean color data for investigating the changes in the water around Taiwan. Fishing data of torchlight fisheries was further provided as a case study to exam the fishing ground variation associated with the upwelling phenomenon in the southern Taiwan Strait. This example guided the students to recognize the biophysical process marine ecology, in which the changes of upwelling in both seasonal and annual scales will cause the vicissitudes of primary production, as well as the fish assemblages and its potential habitat in the surrounding waters.

3.3. “Ocean Literature” Course

Ocean Literature aimed to lead the students to appreciate classic oceanic-focused literary works and engage in discussions about marine and coastal environmental issues. The students were encouraged to identify the ocean images, such as those presented in the award-winner picture book, *Hello Ocean*, its characteristics as described, for example, in Rachel Carson’s *The Sea around Us*, and the conflicts and struggles between humans and the ocean, such as those presented in the classic works *The Old Man and the Sea* by Hemingway and *The Tempest* by Shakespeare. Because literature reflects real life, the students read the scenarios in the literary works and related them to the current environmental issues caused by climate change. Then with sentiments of humanity caring as the basis, the students furthered their exploration and investigation of the protection, reconstruction, and sustainable management of marine and coastal environment. In this way, the course, *Ocean Literature*, was closely integrated with the two courses, *Marine Policy* and *Marine Environmental Science*.

3.4. “Marine and Costal Environmental Education Communication” Course

The course conducted in the second semester, *Marine and Costal Environmental Education Communication*, was the fourth, and last, course provided in the project. Its aim was to integrate and synthesize the professional knowledge and skills the students gained from the previous three courses and, with the higher-order and independent thinking skills they had developed, take action to help solve the problems caused by climate change. In a problem-based learning approach, students reflected on the abstract knowledge gained, and employed the cognitive skills needed for problem-solving,

to come up with self-directed learning goals and strategies in order to solve PBL's ill-structured problems [39]. For the revised model of PBL approach in the course, the ill-structured problem—one having no single correct solution [39], or one being not predictable or requiring the integration of several content domains [40]—was the problem in which the students had to find out how they could help contribute to the sustainability of marine and coastal environment. Through peer collaboration and teacher-student discussion, the students took action learning as their final learning product. They conducted an extension education workshop in two local elementary classrooms to display their willingness and capabilities of helping solving the marine and coastal environmental problems caused by climate change. During the workshops, the students taught the school children about the importance of the protections of corals and the sustainable fisheries. They particularly provided the children with a list of suggested actions so that the school children could follow and therefore also help to protect the marine and coastal environments.

4. Methodology

The methodology framework that guided the design of the study is a trans-disciplinary case study. A case study, in general, is an empirical inquiry investigating a contemporary phenomenon within its real-life context and usually multiple sources of evidence are used [41]. It has been recently argued that a trans-disciplinary case study approach is suitable for scientifically treating large-scale, complex problems concerning the interaction of human environment systems [12]. The present research thus adopts the case study approach so that in-depth descriptions of the trans-disciplinary project can be provided, including student learning experiences and perceptions. In addition, a broader range of contextual and complex conditions can be covered [42].

4.1. Participants

The project was carried out in a regular master's degree program at a southern Taiwan university, prestigious for its education focusing on producing marine affairs professionals. Twelve graduate students enrolled in the program, aging from 22 to 45 years old, were the participants of the project. The graduate students' undergraduate majors varied, such as Marine Leisure Management, Fishery Management, and Marine Engineering. None of them had experience in collaboratively learning with students from different disciplines.

4.2. Data Collection and Analysis

The research team adopted a qualitative research method to collect and analyze the data. A triangulation of data sources was conducted, including the student self-evaluation form, individual student reflection reports, and the observation notes of the video-taped class meetings, which are described as follows:

The students wrote a reflection report at the end of the second semester describing their perceptions of the particular trans-disciplinary learning experience. A constant comparative method [21] was employed when the report contents were closely examined and coded. The research team used an inductive strategy to cluster similar ideas into "increasingly more abstract units" until they established "a comprehensive set of themes" [43]. The findings gained helped answer the first research question, "What are the student perceptions of the learning experiences?"

The participating students also completed a pre- and post-project self-evaluation form, created by the research team. The students were asked about their awareness of marine and coastal environmental protection issues and whether or not they found themselves equipped with the knowledge and skills to deal with the issues. Students circled answers ranging from −3 (greatly decreased) to 3 (greatly increased) to indicate the degree of their awareness, knowledge, and skills. The descriptive analysis method was employed to compare and contrast student answers before and after the implementation of the project. The findings helped answer the second research question, "What are the changes, if any, in the students' attitudes toward marine and coastal environmental protection?"

To answer the third research question, “How do the students display the capability of solving the problems related to marine and coastal environments?”, the primary and second researchers, adopting the participant observation method [22,23] of anthropological research, took observation notes while viewing the video tapes of the class sessions. Videotaping the class sessions allowed the teacher-researchers to remain focused during class activities by later going back to the video clips to closely examine and make observations. In order to gain the greatest understanding of how the students displayed the capability of problem solving, the videotaped fourth course, carried out in the second semester, was the focus of data analysis. The two researchers compared their observation notes and employed a case study research method when using categorical aggregation to establish themes and adopted direct interpretation [43]. Following Azer’s example, a verb list was created [44]. The use of action verbs in assessing students in the revised PBL learning model was to help the researchers observe and analyze the endpoint of student thinking and accordingly evaluate student learning performance and effectiveness [44]. Finally, for the purpose of validity, the research team employed “member checking”, requiring the students to read the interpreted record of the class meetings for accuracy and palatability [45].

A short summary of the data sources and analysis is provided in Table 1.

Table 1. Summary of data collection and analysis.

Research Question	Data Sources	Methods of Analysis
<ul style="list-style-type: none"> What are the student perceptions of the learning experiences? 	<ul style="list-style-type: none"> Student reflection reports 	<ul style="list-style-type: none"> Constant comparative method
<ul style="list-style-type: none"> What are the changes, if any, in the students’ attitudes toward marine and coastal environmental protection? 	<ul style="list-style-type: none"> Pre & post-project self-evaluation forms 	<ul style="list-style-type: none"> Descriptive analysis
<ul style="list-style-type: none"> How do the students display the capability of solving the problems related to marine and coastal environments? 	<ul style="list-style-type: none"> Teacher observation notes Video clips of the workshops 	<ul style="list-style-type: none"> Content analysis

5. Results

5.1. Student Perceptions of the Trans-Disciplinary Learning Experiences

The analysis of the student final reflections indicated that most students began the project feeling intimidated. This mainly resulted from the totally new learning experience of the trans-disciplinary project, taking four courses altogether outside of their academic expertise while working with peers from diverse learning backgrounds. As Kuan (pseudonyms are used throughout the article and translations made from Chinese) pointed out, the trans-disciplinary project made her feel challenged in the beginning.

However, as time went by, the teamwork that the students developed with their peers sustained the students throughout the project. Their reflections showed that at the end of the project they gained confidence and satisfaction about this special learning experience. Kuan commented that after she and her peers spent time discussing and negotiating, she felt that “things became clearer”. Kuan concluded: “When in the end we saw what we had come up with as our final product, I had this sense of satisfaction about the progress we had made together”.

The teachers’ support and trans-disciplinary collaboration also contributed to student growth. Simply put, because the teachers are experts in various fields, what they can offer is therefore rich and diverse. Consequently, through their co-teaching, the students taking the courses could see things from various points of view and gained knowledge in multiple aspects. Student Yen summarized as

follows: “In the past, my understanding of the ocean was limited to one subject. However, through the trans-disciplinary project, I now have developed a brand new thinking style. *Marine Policy* is no more about laws and principles only. It has to be considered by integrating the ideas and spirits we gained from literature and science” (student reflection).

The effective peer collaboration and sufficient teacher support allowed the students to appreciate the innovative way of learning. The students, stepping out of the “comfort zone” of a traditional mode of learning, took ownership of what they learned, caring about how well they could perform and how successfully they could deliver what they had learned to others. For example, Kuan wrote in reflection: “I found the most challenging part was trying to find a way to transform the advanced knowledge into amusing activities to approach the children. This is a real life issue to us and we cannot just take it lightly or casually. I would like to see that not we alone benefit by what we have learned; I would also like to help cultivate the next generation” (student reflection). Such a statement suggests that the students had evolved from learners being engaged to learners engaging others.

The students also recognized that they had developed more higher-order thinking skills after participating in the project, a result very likely caused by the PBL approach. As the researchers observed, throughout the process of both independent and peer learning, the students displayed not only the abilities of understanding and applying the knowledge they gained, but also the capabilities of analyzing and evaluating it. Above all, the students expressed the willingness and enthusiasm to reconstruct the knowledge and therefore create a new set of knowledge that can benefit others. When interviewed, student Yieh pointed out that he was adopting the role as a learner when taking the courses. However, when asked what kind of role he would be taking in the future, he answered without hesitation: “I would like to be a policy maker, who decides on the directions and makes the policy”. Such an answer depicts the students’ perceptions of themselves from a role of learner, observer, and participant to that of a leader and reformer.

5.2. The Changes of the Student Attitudes toward Marine and Coastal Environmental Protection

The mean scores of the pre- and post-project self-evaluation answers were compared (Table 2), and the results revealed that by the end of the project, almost every category received higher scores. Three categories showed particularly great improvements, including “I will actively participate in the workshop and research about marine science” (with 1.9 as the gain score), “I will actively participate and be engaged in ocean humanity organizations and activities” (with 1.6 as the gain score), and “I can actively participate in the workshop and research related to the implementation of marine technology” (with 1.1 as the gain score). In other words, the students showed much greater improvements in their willingness to actively participate in marine and coastal issue-related activities and organizations, which may well suggest that the project has succeeded in developing students’ autonomous and independent learning.

For those categories that did not experience such a drastic change, it was often because of the initial high scoring students gave those items in the pre-test survey. For example, the statement: “I can feel the influences of the ocean on human spirits, minds, and bodies.” The gain score is 0, and both pre and post scores are 1.8, which suggests that the students had already been aware of the influences of the ocean even before they participated in the project. A similar result was found in students’ answers to another survey statement regarding marine-related issues in terms of sovereignty and ecology. This may be explained by the fact that Taiwan is an island nation, whose inhabitants have grown up around marine-related situations. Furthermore, the students all studied in a university offering marine-related professional training. Therefore, it stands to reason that they had pre-acquired knowledge in these aspects.

Table 2. Mean scores of student self-evaluation form.

No.	Category	n	Pre Mean	Post Mean	Gain Score
1	I can feel the influences of the ocean on human spirits, minds, and bodies.	12	1.8	1.8	0
2	I will pay particular attention to issues concerning marine systems and humanity, such as the ups and downs of fisheries.	12	1.5	2.2	0.7
3	I will actively participate and be engaged in ocean-humanity organizations and activities.	12	0.4	2	1.6
4	I will learn the knowledge of marine science, such as the relationship between ocean currents and the climate, and the bottom configuration around Taiwan.	12	1.2	1.8	0.6
5	I will especially try to understand the knowledge related to marine science.	12	1.1	1.8	0.7
6	I will actively participate in the workshop and research about marine science.	12	0.1	2	1.9
7	I have acquired the knowledge of marine laws, such as international laws of the sea.	12	1.2	1.6	0.4
8	I can understand national and international laws and principles of the sea.	12	1.4	1.6	0.2
9	I will actively participate in the workshop and research about the laws of the sea.	12	0.4	1.2	0.8
10	I can understand the marine literacy and related professional terminology.	12	1.4	1.8	0.4
11	I can use English (or other non-native language) to share and discuss with others about the issues related to the ocean.	12	0.9	1	0.1
12	I can use English (or other non-native language) to read and write about issues related to the ocean.	12	0.8	1	0.2
13	I have read and listened to ocean literary works, movies, and music.	12	1.5	1.6	0.1
14	I can understand the contents and meanings implied in the classic ocean literature.	12	1.5	2	0.5
15	I can share and discuss with others my ideas about the ocean classics, including literature, movies, and music.	12	1.3	1.8	0.5
16	I can adapt from or rewrite ocean literary works.	12	0.6	1.4	0.8
17	I can create ocean literary works, such as poems, essays, or short films.	12	0.8	1	0.2
18	I can create ocean-related works, such as novels, movies, and music, etc.	12	0.5	0.8	0.3
19	I can understand marine science and the implementation of marine techniques.	12	1.0	1.2	0.2
20	I can actively participate in the workshop and research related to the implementation of marine technology.	12	0.3	1.4	1.1
21	I can use the marine techniques and knowledge to solve related problems.	12	1.0	1.2	0.2
22	I can understand the rights and obligations about the ocean, such as sovereign rights in the ocean, marine ecology protection, etc.	12	1.6	1.6	0
23	I can actively participate in the activities and affairs related to marine rights and obligations.	12	1.2	2	0.8

5.3. How the Students Displayed the Capability of Solving the Problems Related to Marine and Coastal Environments

The videotaped class meetings of the course, *Marine and Coastal Environmental Education Communication*, were analyzed. The action verb list that the researchers came up with described the researchers' interpretation of student acts, which included such verbs as "ask", "brainstorm", "activate", "choose", "negotiate", "discuss", "recognize", "self-learn", "integrate", "present", "reflect", "evaluate", and so on. All these verbs indicated that the students were able to conduct high-order thinking, which is a very important characteristic for solving problems. The following are two examples of the action verbs: "The students *recognized* their incompetence when preparing for the workshop learning contents. Then they *self-learned* to expand their understandings".

The researchers' observation notes supplemented the findings gained from the content analysis of the video clips. As the constant comparative method was employed throughout the process of data analysis, working across the various data sources allowed the researchers to come up with a more

thorough understanding of student capabilities of solving the problems caused by the climate change. Table 3 gives a number of examples.

Table 3. Examples of student capabilities of solving the problems caused by the climate change.

Current Problems	Student Actions	Examples
Declining mullet fisheries	<ul style="list-style-type: none"> Exemplifying 	<ul style="list-style-type: none"> Giving examples to school children that it was becoming more expensive to buy a bowl of mullet noodles.
	<ul style="list-style-type: none"> Implementing 	<ul style="list-style-type: none"> Leading school children in playing games with the information about mullets integrated within.
Flood	<ul style="list-style-type: none"> Analyzing 	<ul style="list-style-type: none"> Analyzing the causes of flood in Linbian Township in 2009.
	<ul style="list-style-type: none"> Creating 	<ul style="list-style-type: none"> Thinking of an alternative way, such as stand-up paddle surfing at the fish farms, to replace the traditional aquaculture.
Coral Bleaching	<ul style="list-style-type: none"> Synthesizing 	<ul style="list-style-type: none"> Commenting that waste water discharge, inappropriate management of coastal recreation activities, over-harvesting of marine organisms, and in-washed sediment caused by heavy rains were the reasons leading to coral bleaching.
	<ul style="list-style-type: none"> Relating 	<ul style="list-style-type: none"> Recalling personal experience of visiting the Pratas Island where the white sand was actually the bones of corals.

6. Discussion and Conclusions

The findings of the present study indicate that the students generally held positive opinions toward the project. Their attitudes changed from hesitancy toward an unfamiliar learning method, to an embracing of their broadened horizons and independent learning skills. Beyond just a favorable outlook on how the project benefited themselves, the students also exhibited increased consciousness and concern for marine and coastal sustainability, as was indicated by the post-project survey, and increased capability for practical problem solving as was observed through the researchers' coding of observed action verbs.

A synthesized summary of the implications of the present study follows.

6.1. The Trans-Disciplinary Curriculum Stands to Be an Innovative yet Indispensable Design for Coastal Management Education

In the present study, the trans-disciplinary project integrated four courses. Although each had an individual course syllabus, the course contents were intertwined and the course goals were consistent. The research team suggests that two major characteristics of course integration, proposed by Beane, should be followed: The curriculum design should begin with an examination of real world problems, issues, or concerns of life: for example, in the present study, the investigation of marine and coastal environmental issues. Secondly, the design of curriculum should transcend subject-area and disciplinary identifications, revolving "around projects and activities rather than subjects" [46]. For example, in the present study, the students were asked to participate in various workshops, made several field trips, and completed multiple group tasks to gain and share understandings of the focus themes of the project. Consequently, the learning would become meaningful to the students because

the instructions were organized around environmental issues rather than being done in disconnected units in different subject areas [14]. Moreover, because the themes were drawn from real-life concerns, what the students learned would help them solve the real problems in the future rather than remain 'static' and 'transmitted' knowledge.

6.2. The Trans-Disciplinary Projects Benefits Students by Equipping Them with Essential Knowledge and Skills to Succeed in Future Marine Conservation

The trans-disciplinary design of curricula has proved to be beneficial to the students in the present study, in terms of their enhanced knowledge and skills and their inspired affection. Starting with the essential skills, in Langholz & Abeles' study, innovation, collaboration, and communication were considered the three most essential skills needed to succeed as leaders in marine conservation [47]. When analyzing the data, particularly the student activity verb list, the teaching-research team found that the trans-disciplinary project engaged the students in active peer collaboration and allowed the students to learn negotiation and communication with their group members. All the skills thus acquired should help the participating students to become even better marine professionals in the future.

The students' reflections also suggested that the trans-disciplinary design of curricula, although it might have appeared challenging to them in the beginning, was appreciated later as the students became more engaged in the course activities. Through the PBL approach, the students not only learned from the instructors, they particularly learned from their peers and by self-teaching. When encountering the existing problems caused by the climate change, the students displayed that they were able to resolve the problems by employing higher-order thinking skills. As the students celebrated their growth as more independent and sophisticated learners, the potential for them to become the leaders in marine and coastal environmental education was also developed.

6.3. Action Learning for Marine and Coastal Sustainability Serves to Be the Final Goal of Trans-Disciplinary Learning Project

It is proposed that the end of learning is action, not knowledge (Action Learning Associates). According to scholars, an action learning process must be designed in a way that self-organizing competencies can be developed, enabling learners to act independently, focused and performance-oriented [48]. Trans-disciplinarity stresses the interconnection of science disciplines and social contexts, which means reaching out beyond science to include aspects of practical contexts and to feedback results to practical actions [49]. Therefore, the final goal for trans-disciplinarity is playing out in practice and enabling researchers and practitioners to jointly create knowledge production and thereby increase the effectiveness and applicability of research results [46]. Following that argument, student action learning as a learning end has become desired in a trans-disciplinary curriculum design.

In the present study, the students, when enrolled in the fourth course, *Marine and Coastal Environmental Education Communication*, decided that conducting extension education workshops at the local elementary classrooms were the means for them to devote to marine sustainability. They created course syllabus and led the school children through interesting learning activities so that the latter's curiosity and knowledge for the marine environment related issues were enhanced. By conducting the workshops, the participating students in the study not only put what they had learned into practice, but also contributed to the sustainable management of marine and coastal environment. In Huang and You's study, they indicated that the public in Taiwan were more aware of international issues, than the Taiwanese marine policies [50]. In this sense, the workshops conducted by the participating students served a meaningful final goal for the project.

6.4. A Trans-Disciplinary Case Study on the Design of Curricula Provides Effective Knowledge Integration of Marine and Coastal Sustainability

Although many studies have been carried out in recent years to examine the benefits of trans-disciplinary programs in sustainable development [12,50–54], few studies have been conducted to exhibit in detail the organization as well as effects of the integrated courses. The present research adopted a trans-disciplinary case study to carry out an up-close, in-depth, and detailed examination of a case, that is, the trans-disciplinary curricula lasting one year and integrating four courses instructed by scholars from various academic backgrounds. Such a case was investigated from a specified perspective and with a special interest [50]. By adopting the qualitative case study method to closely examine the student learning experiences and perceptions, the teaching-research team was able to obtain rich understandings of the multi-faceted experiences of a single instance [55]. Moreover, the interconnection of the integrated courses was thoroughly introduced and discussed, which should help initiate the setup of a program module and later be applicable for other pedagogical practices and studies.

It has been argued that engaging the public with climate change still proves to be a significant challenge [56]. When seeking to solve the problems caused by climate change, the research team pleads for a thorough discussion and examination of education programs. As Nelson Mandela said: “Education is the most powerful weapon which you can use to change the world”. The research team believes that the setup and continuous implementation of the trans-disciplinary curricula can help engage the public to deal with the current problems. There is no denying that a systematic evaluation framework is needed if the design of curricula wishes to be scientifically investigated and approved. A larger number of participants is also required. In addition, teacher’s perspectives and experiences in participating in such projects are also required. The school children’s perceptions of the two workshops conducted by the graduate students in helping them become more aware of the marine and coastal environment issues should also be investigated. In that way, a more thorough understanding of the impact of such a project can be obtained. Therefore, for future research, all these can be taken into consideration. However, for the time being, this present study serves to start an effective discussion on how marine and coastal management issues can be resolved.

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