The Development of a Virtual Coastal Ecological Environment for Science Education: A Case Study of Hsiangshan Wetland at Hsinchu, Taiwan

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Abstract: This study developed a web-based virtual coastal ecological environment to create the landscapes of Hsiangshan wetland at Hsinchu, Taiwan using network and virtual reality technologies. The users can experience riding a bicycle through the coastline and using binoculars to observe biological species in the wetland area, e.g., the movements and foraging behavior of fiddler crabs and the growth patterns of coastal and sand-stabilizing plants. The simulation programs obtain real-time data from the Central Weather Bureau of Taiwan to reproduce the tidal height and rotation speed of wind turbines for users to visualize the environmental changes along Hsinchu coastline. The virtual coastal ecosystem is rich in contents and provides interactive user interface to enhance the knowledge about Hsiangshan Wetland. The virtual coast ecosystem can be used as an assistant tool in primary science education, and it is helpful in increasing students’ learning motivation and effectiveness regarding wetland ecology.

Keywords: virtual reality, virtual coastal ecological environment, Hsiangshan Wetland, science education.

1. Introduction

The 17 km coastline of Hsinchu City is famous for being contiguous to the largest intertidal Hsiangshan Wetland in northern Taiwan. For travelers driving on the West Coast Expressway, Hsiangshan Wetland has always been one of the major scenic spots for sightseeing and resting. The sceneries vary with the tides, thereby giving the coast a diverse look during different times of a day. With the active development of Hsinchu City Government, the tourists can find along the 17 km coastline a viewing platform at Haishan Fishing Port, a sea-viewing park for leisure and environmental protection, the unforgettable Horizon and Sea Viewing Area, the elegant Chinese arch bridge upon the Gangnan Canal, and a Kandelia Candel forest at the Mangrove Park. Also, the Hsiangshan sunset over the splendid coastline is so fascinating that it always makes people linger for a long time. Thus, riding a bicycle along the 17 km coastline is a good choice of holiday’s leisure activities for Hsinchu citizens.

One can also visit the various ecological protection areas of Hsiangshan Wetland to see different kinds of wild birds and crabs [1]. For example, soldier crabs (Mictyris), sentinel crabs (Macrophthalmus), and other kinds of crabs appearing at the intertidal zone are very interesting and eye-catching. Nangang Wetland, as a part of Hsiangshan Wetland to the south of Haishan Fishing Port, is the main habitat of Taiwan’s fiddler crabs; while the Chincheng Lake area, also included in the Hsiangshan Wetland and located at the northern bank of River Keya, is an important habitat for a large number of waterbirds. Hsiangshan Wetland has a valuable contribution to ecosystem protection and, in specific, the wetland preserves biodiversity, purifies water, controls water flows, thereby preventing floods and disasters, regulates carbon levels, and houses many seashore creatures that are worthwhile for us to know and understand. As a result, the wetland is the best place for a field trip, especially for the purpose of ecology education.

Global warming is a serious problem [2], which causes fast melting of polar ice caps, rising of sea level and strong convection currents. Wind and flood hazards resulting from dramatic climate changes force people to bring greater focus onto environmental issues. The main causes of environmental problems are overexploitation of natural resources, massive amounts of garbage produced by large population, waste gases, and toxic materials [3]. These lead to climate changes and environmental deterioration, and cause various biological resources, or the so-called biodiversity, to gradually disappear. Wetlands play an important role in biodiversity preservation, including water retention and purification, flood and disaster prevention, and climate regulation. There are many kinds of creatures living on wetlands as well. Making important connections between life and natural environments, wetlands are often referred to as the Earth’s kidney. As climates and environments continue to worsen, wetland areas have been decreasing daily. Therefore, educating future generations on wetland protection is a very important issue.

As the Internet is getting more popularized, people obtain information more conveniently. A lot of knowledge can be efficiently acquired through web searches. Therefore, the Internet can be used as a very suitable teaching assistant tool. Web-based learning activities satisfy the needs of different learners and are not restricted by time or space, thus supplementing classroom teaching materials [4]. Virtual reality, created by computers with special software and hardware, allows users to have real-time interaction with other people or virtual objects in the virtual world [5]. Applications of virtual reality in fields such as science, engineering, national defense, education, and entertainment have been highly valued recently because a virtual environment can prove to be “almost real”. It can give a sense of reality while avoiding the danger and costs of being in a real environment [6].
This study combines the attractive features of web-based learning and virtual reality to set up a virtual coastal ecological environment according to Hsiangshan Wetland, which can be used as an assistant teaching material in science education for elementary and junior high school students, promoting the concepts of environmental education and nature conservation. Through the Internet, students can observe and experience the ecological and environmental changes at Hsiangshan Wetland to understand the related knowledge and importance of coastal ecological environments. In the virtual coastal ecological environment, learning activities are designed by simulated real situations using computer and virtual reality technologies. Learners actively obtain and build new knowledge based on their needs; the learning style agrees with constructionism [7] and situated learning theory [8]. After the system was developed, this study performed user analysis through questionnaire surveys and conducted interviews with science teachers as a reference for future improvements.

2. Research Method

This study comprises two stages: the first stage is planning and analysis, and the second stage is design and production (Figure 1). In the first stage, researchers personally visited Hsiangshan to conduct an investigation by taking many photos for references in the second stage such that the designed virtual environments were similar to the natural ecological sceneries. After the field investigation, related literatures were collected, e.g., information about the representative living creatures at Hsiangshan Wetland and their ecological models, the map of the 17 km Coastline, and a tide table. Then, the collected information was organized and analyzed. After asking for the suggestions from scholars and experts, the virtual scenes and kinds of living creatures for development were determined.

As the model of the virtual coastal ecological environment was determined, the technical aspects based on the required functions were analyzed to ensure their feasibility, for example, the functions of virtual binoculars to observe fiddler crabs and tidal changes as well as a coordinated map for guiding tour. Adopting the suggestions of scientific experts and scholars, the objective of this study was to present the natural ecological environment of Hsiangshan Wetland and the learning contents in the virtual ecological system were decided as various kinds of fiddler crabs and seashore plants.

This study employed a modulized design method. Based on each scenery’s geographical location, coastline views, and natural ecological environment, three ecological areas were included for exhibition: Keya Estuary, the Splendid Coastline, and Haishan Fishing Port. This study designed these sceneries based on their real ecological environments by referring to the photos taken during the field investigation. Once the design was finished, it was integrated to a webpage using a Java Script program. Then, following the instructional design, the system was presented in a webpage format for elementary and junior high school students to explore.

To understand students’ opinions after using the virtual coastal ecological environment, this study carried out a user test after the website had been completed. The system’s performance was examined through the user test as well as the questionnaire surveys and the interviews with science teachers. Furthermore, the results can serve as a reference for improving the system design and website contents in the future.

3. Scenery Planning and Design

The major tasks for setting up a web-based virtual coastal ecological environment include the development of virtual sceneries (including the models of fiddler crabs and seashore plants), control programs, teaching materials, and the website. This study used the map of Hsinchu’s scenic spots as the blueprint and planned the following sceneries: Keya Estuary, Splendid Coastline, Haishan Fishing Port, as well as a bicycle route to connect each scenic spot. Each of the sceneries has different contents and teaching objectives (Figure 2).
this study designed the virtual scenes based on various kinds of fiddler crabs and seashore plants as well as their living environments at Hsiangshan Wetland. The display contents of in Keya Estuary includes the commonly seen mangrove plants, fiddler crabs (i.e., *Uca lactea* and *Uca arcuata*), and grapsid crabs (*Helice formosensis*). In the Splendid Coastline wetland, one could observe fiddler crabs, sentinel crabs, and soldier crabs (*Mictyris brevidactylus*). As for Haishan Fishing Port, the ecological environment and seashore plants are rich and plentiful. To better utilize the viewing platform and wind turbines, functions for observing tidal changes and wind speeds were designed.

This study also simulated riding a bicycle to connect each scenic spot. During the ride, users could appreciate beautiful sceneries along the 17 km coastline, e.g., Hsinchu Fishing Port, the Horizon and Sea Viewing Area, and Gangnan Canal. After arriving at an ecological area, one could appreciate the natural scenery and observe living creatures using binoculars, e.g. the movements and foraging behavior of fiddler crabs, the growth of seashore plants, and so on.

### 3.1 Keya Estuary

The mangrove area of Keya Estuary is a scene designed based on real scenery. From Hsinchu Nanliao Fishing Port, one can ride along the bicycle route of 17 km coastline, pass through the large mangrove forests behind Chincheng Lake, and then arrive at Keya Estuary, a winding beach estuary with natural barriers at the outer edge and suitable for the growth of mangrove forests. The mangrove forest is a mixture of two seashore plants, i.e., gray mangroves (*Avicennia marina*) and *Kandelia candel*. The tree bark of gray mangroves is thin and smooth; the aerial roots and the breathing roots protruding from the ground give them a very distinct outlook. For *Kandelia candel*, the plants grow in a large quantity and their fallen leaves and seedlings are important food sources for many animals living under the mangroves. The virtual scene of Keya Estuary was developed based on the photos taken in field investigations (Figure 3). The primary objects here includes a bicycle route, a rainbow bridge, the Keya River, an ecological area for fiddler crabs, and mangrove forests.

![Figure 3. The virtual scene of Keya Estuary](image)

### 3.2 The Splendid Coastline

The Splendid Coastline is famous for being contiguous to Hsiangshan Wetland, and its scenery varies according to tides, thereby giving the coast a diverse look. Nurturing abundant intertidal living creatures, Hsiangshan Wetland is the natural ecological area most accessible and provides the greatest ecological resources along Hsinchu coastline. Many pavilions are set up along the bicycle route in the Splendid Coastline. The roof of pavilions is wavelike and matched with interchanging blue and white colors, which are very eye-catching. In addition to keeping out rain and sun, the pavilions can also beautify the environment. This area has a large quantity of fiddler crabs. This study has chosen three kinds of representative fiddler crabs, i.e., *Macrophthalmus, Uca lactea*, and *Mictyris brevidactylus* for display. The size of fiddler crabs is small and not easy for observation. Therefore, this study designed the function of binoculars that can magnify the visual field to an observable scope (Figure 4). The main objects in the virtual scene of the Splendid Coastline include: blue-and-white wavy pavilions, a bicycle route, and a large area of wetland under the ramp way with different kinds of fiddler crabs.

![Figure 4. The virtual scene of the Splendid Coastline](image)

### 3.3 Haishan Fishing Port

Due to the tidal influence, the fishery of Haishan Fishing Port is not as flourish as that of Nanliao Fishing Port. Therefore, Hsinchu City Government took the initiative to build some recreation facilities inside the fishing port. Also, there is a sea-viewing platform at the north-end channel to provide a vantage point for watching tides, beautiful scenery, and the rafts for collecting oyster. On the sand dunes beside Haishan Fishing Port are many seashore plants, including: littoral spinegrass (*Spinifex littoreus*), shoreline purslane (*Sesuvium portulacastrum*), dodder (*Cuscuta*), beach morning glory (*Ipomoea pes-caprae*), five-leaf chaste tree (*Vitex negundo*), and seepweeds (*Suaeda maritima*).

Near Haishan Fishing Port are some huge wind turbines for generating electricity, forming a special view of 17 km coastline. In the virtual scene of Haishan Fishing Port, this study designed a sea-viewing platform, a fluctuating sea level showing tidal changes, and several wind turbines with a unique appearance (Figure 5). Moreover, this study designed a program to obtain real-time data from the Central Weather Bureau of Taiwan to simulate the tidal height and rotating speeds of wind turbines so that users could know the changes in tide levels and wind strength in Hsinchu coastline area.
3.4 Virtual Bicycle Route
The bicycle route of 17 km coastline at Hsinchu starts from the Environmental Protection Park at Nanliao Fishing Port and ends at the south bank of Yanggang Estuary. Along this route, one passes by Nanliao Fishing Port, windbreak forests, Sea Viewing Park, the Horizon and Sea Viewing Area, Gangnan Canal Scenic Area, mangrove forests, the Splendid Coastline, Nangang Bird Watching Area, and other scenic spots. Each scenic spot has its special features and thus the scenery of bicycle route is considered the most unique in north Taiwan. In this study, the main function of the virtual bicycle route is to make connection between scenic spots such that users could travel back and forth in a relaxing way and appreciate the beautiful coastal sceneries.

The virtual bicycle route was designed to imitate the curvy topography of Hsinchu coastline. Along the path, streetlights and fences were set up (Figure 6). Beside the bicycle route were many wave-dissipating concrete blocks, forming a common feature on Taiwan’s west coast. In the virtual coastal ecological environment, users could switch scenes by clicking on the tour map at the lower left corner of the webpage or the bicycle in the virtual scene to enter the 17 km coastline, and the latter would take about 30 seconds to reach the scene. This study used a computer program to simulate the bumping visual effects when the users are on a bicycle, making them have an immersive feeling of actually riding a bicycle.

4. System Implementation
Based on the natural ecological environment of Hsiangshan Wetland, this study planned for three virtual scenes, including Keya Estuary, Splendid Coastline, and Haishan Fishing Port. In addition, a bicycle route connecting scenic spots was also designed. The virtual scenes were designed according to the original look of each scenic spot. Also, the characteristics of ecological environment were taken into consideration. With limited file sizes, how to utilize the collected information to create rich and appealing contents suitable for each scenic spot’s ecological environment is very important.

4.1 Scene Model
To produce a realistic effect, objects with strong features or high recurrences were chosen as the main subject in designing the scenes. Taking the mangrove forest in Keya Estuary as an example, the object with the strongest feature is the rainbow bridge that crosses Keya Estuary and connects to the bicycle route. The highly recurrent object is the fence on both sides of the sidewalk. Special care needs to be taken when making highly recurrent objects. If the model of an object is complex, then using a computer program to copy such an object would cause a heavy computational burden. Copying without using a computer program saves the computation time, but the file size would increase. Sometimes, considerations must be taken in terms of saving time or file size. After the objects were created, they were inserted into virtual scene and some adjustments were made on their sizes and locations. The 3D model of this scene was then completed (Figure 7).

4.2 Designing Background Image
The design and mapping of background images have a great influence on the reality of the virtual scenes. This study used the repeated mapping of horizontal mirror method to design the background images for the scenes. Using this method, photos taken on-site can be modified to form a surrounding background image. The process is simple with realistic effects being achieved as well. First of all, this study picked a suitable photo taken at the scenic spots; the guideline for choosing the photo was that the content should be simple and correspond to the surrounding environment of the scenic spot. Then, the applicable portions were cut out using image-processing software with the sky removed or adjusted to light blue color.
Finally, the horizontal mirroring method was employed to make a continuous background image. Taking Figure 8 as an example, picture B, mirrored from picture A, is placed at the right and left sides of picture A, so the borders of these pictures can be completely merged and therefore a continuous background picture can be obtained.

Figure 8. Designing the background image by the horizontal mirroring method

This study set up a continuous background image around the virtual scene (Figure 9). Looking out from the inside, users can see the background image without discontinuity problem. Although the background image would result in a circular gap right on top of the center, this study used a program to set the background color of the above space as white color. Since the background image of the sky is also white, they can be merged smoothly to solve the discontinuity problem. Another way of mending this problem is to limit the elevation angle of the camera or to add a white cover at the top.

Figure 9. Designing background images for the virtual scene

4.3 Designing Models for Seashore Plants
Seashore plants play a significant role in the coastal ecological environment. This study selected eight kinds of representative plants, including two mangrove plants and six seashore plants. Based on the appearances and features of the plants, this study used the cross-mapping method and the traditional modeling method to develop 3D models of the seashore plants. For the above two methods, each has its advantages and disadvantages. The former is simple and saves computer resources, but can not present the detailed structures of a plant. For seashore plants requiring a close observation, the models must be built based on their characteristics so that the original looks can be presented. In that case, more design efforts and computation resources are also required. Therefore, one can choose the method best suits the design objective.

Another important part to be considered is the computation speed. In a virtual scene, the number of polygons of an object is closely related to the computation time. The advantage of the cross-mapping method is using a few polygons to achieve acceptable visual effects for the static objects such as flowers, grass, and trees. Taking the model of Kandelia as an example, this study first cut out the shape of Kandelia from the image to produce a transparent counterpart and then overlapped it to the original image for display. The black portion of the image can be ignored by a program to achieve the effect of transparency. Afterwards, two or more images were interlaced at the center axes to form the cross-mapping model (Figure 10).

Figure 10. Designing Kandelia model by cross-mapping method

Growing on seashore dunes, beach morning glories sprawl on the ground to expand their territories. Using cross-mapping method to develop the model for this plant is appropriate. Thus, this study directly followed its appearance and characteristics to build the model, which was then mapped with textures of leaves and branches (Figure 11).

Figure 11. Designing the model of beach morning glories

Usually, there are a lot of sand-binding plants on the beach. To produce such a visual effect, this study used a computer program to duplicate a lot of them and arbitrarily adjust the angles of the duplicated objects. Also, the duplicated beach morning glories needed to be connected to each other. Finally, a virtual scene with a large number of the beach morning glories strung together was produced (Figure 12).

Figure 12. Duplicating a lot of beach morning glories
4.4 Designing Models of Fiddler Crabs

In this study, eight kinds of fiddler crabs that could better represent the crab species in Hsiangshan Wetland were chosen. Based on their appearances, 3D models of the fiddler crabs were designed and image-processing software was used to obtain the required texture images for mapping. When the 3D models were developed, a bone system was added to the models to simulate the behavior of fiddler crabs, such as foraging, moving, and sand-grain disposal. Then, the model was duplicated using a computer program to meet the required quantity. Through PHP and JavaScript programs, parameters were delivered to make interactions with users.

- 3D Modeling

To produce realistic effects in modeling fiddler crabs, the researchers visited Hsiangshan Wetland to observe various fiddler crabs and used a video camera to record their motions, which could be used as a reference for designing the crabs’ 3D models. This study used 3ds Max [9] to create the 3D models of fiddler crabs. During the design process, various parts of the crab were made separately and then assembled together to form the crab model. Reducing the number of polygons for the 3D model was taken into consideration, which is important especially when a scene has a large number of fiddler crabs. Figure 13 is the 3D model of *Mictyris brevidactylus*.

![Figure 13. The 3D model of Mictyris brevidactylus](image)

- Designing Images for Texture Mapping

After the 3D model of a crab was built, the images for texture mapping were drawn and pasted to the surface of the crab model (Figure 14). Basically, the resolution of image has a great influence on the reality of crab models. An image with a higher resolution can make the model look more realistic, but the file size is also larger and not favorable for downloading. Therefore, designers had to consider the actual needs to decide on the image resolution for mapping.

![Figure 14. Pasting image to the surface of a crab model](image)

- Designing the Motions

This study added a bone system to the crab model to simulate its dynamic effects. Through spatial coordinates and collision detection, the location of the crab model after a movement can be calculated. Although using more joints can simulate more complex motions, the computation time will also increase. This study analyzed the features of fiddler crabs’ motion based on the recorded video. Then, based on the needs of displaying, two to four sets of dynamic effects were planned. Taking the dynamic motions of *Mictyris brevidactylus* as an example, the motion of foraging is more complex and thus 40 frames were used for presentation; the walking motion is simpler, so only 24 frames were required (Figure 15).

![Figure 15. The crab’s motions of foraging and walking](image)

- Types of Fiddler Crabs

This study planned three major sceneries for the virtual coastal ecological environment: Keya Estuary, the Splendid Coastline, and Haishan Fishing Port. Traces of fiddler crabs could be found in all these sceneries. In order to present the ecological habits and characteristics of the fiddler crabs in the coastal wetland, this study selected eight representative fiddler crab species for displaying in the above three sceneries, i.e. sand bubbler crabs (*Scopimera bitympana*), ghost crabs (*Ocyopode stimponsi*), soldier crabs (*Mictyris brevidactylus*), fiddler crabs (*Uca lactea*, *Uca arcuata*, and *Uca formosensis*), graspid crabs (*Helice formosensis*), and ocypodid crabs (*Macrophthalmus banzai*).

4.5 Tidal Changes and Wind Speed

In the scene of Haishan Fishing Port, this study designed a function that could indicate changes in tides and wind speed. Through the control of a program, the computer would adjust the scene’s tidal height based on the real-time data provided by the Central Weather Bureau of Taiwan. The users can see a high tide as sea level rises and a low tide as sea level falls. Also, the huge wind turbines near the fishing port would also change their rotating speed when the real wind speed changes.

At Haishan Fishing Port, the Central Weather Bureau has set up a climate observation station to collect and transmit data in real time to the bureau server, thus keeping updated with the latest information. This study uses a PHP program on the VR server to access the real-time information from the bureau server; the data is passed to the virtual scene of Haishan Fishing Port. When the users enter the virtual scene of Haishan Fishing Port, the PHP program will analyze the data obtained
from the Central Weather Bureau to compute the tidal height and wind speed. The information is then transmitted to the control program of the virtual scene to change the sea level and the rotating speed of wind turbines (Figure 16).

**Figure 16. Changing the tidal height and wind speed according to the real-time data**

### 4.6 User Guide

In this study, the virtual coastal ecological environment was presented in a webpage format. The URL of the website is http://vr.nhcue.edu.tw/crab. The users can visit the website using a web browser (Figure 17). For the first-time users, the computer would automatically download a plug-in program. Once the installation is completed, the system is ready to be used. Users were recommended to set the screen resolution as 1280×1024 for a better visual effect. After entering the virtual coastal ecological environment, the users could select the parts of interest to visit and study.

**Figure 17. The website of virtual coastal ecological system**

For convenience, this study designed several buttons on the homepage, including “Tour Map”, “Introduction to Scenic Spots”, “Related Websites”, “Website Information”, “Tidal Changes”, “Contact Us”, and “Back Home”. The following is a brief introduction of their functions:

- **Tour Map**
  Clicking on the “Tour Map” button, the map of 17 km coastline is shown and a bicycle icon is used to indicate the user’s current location. The main scenic spots in the map include Mangrove Park, the Splendid Coastline, and Haishan Fishing Port. Clicking on these links, the user can enter the virtual scenes immediately.

- **Introduction to Scenic Spots**
  Clicking on the “Introduction to Scenic Spot”, a description about the present scene is shown under the menu. Based on the introduction, the user can gain a better understanding about the ecological environment in this scene.

- **Related Websites**
  Clicking on the “Related Websites” button, many hyperlinks about ocean ecology, biodiversity, and Hsiangshan Wetland are shown. Through these professional websites, the users can obtain more information related to coastal ecology.

- **Webpage Information**
  Clicking on the “Website Information” button, a summary of the website information is shown. The contents include a fiddler crab film and its introduction, seashore plants, learning units, and detailed information about various scenic spots.

- **Tidal Changes**
  This topic has already been described earlier.

- **Contact Us**
  Clicking on the “Contact Us” button in the menu, the user is directed to the administrator’s webpage where the contact information of the administrator can be found.

- **Back Home**
  Clicking on the “Back Home” button, the user can go back to the home page immediately, regardless of his or her current location on the website.

### 5. User Analysis

To understand the users’ opinions about the virtual coastal ecological environment, this study carried out a user analysis on elementary school students and had interviews with their science teachers. The analysis and interview results could be used as the reference for system improvement in the future. The test samples were 28 fourth graders in an elementary school at Hsinchu and the test was taken at their computer classroom. During the testing process, students first operated the system and then filled out questionnaires (Figure 18).

**Figure 18. Conducting a user test at an elementary school**

This study prepared a few learning units based on each virtual scene’s ecological environment and functions. At first, the observation points and operation methods were explained by their science teacher using PowerPoint. Then, a number of questions were provided, which required students to find out the answers from the website. During the testing process, the
teacher observed how students used the system and assisted them in solving operational problems.

5.1 Questionnaire Results
This study designed the questionnaires according to Lin’s assessment standards [10] for the quality of children’s learning websites. The purpose was to understand elementary students’ ideas regarding the contents of the virtual coastal ecological environment, user interface, and the system applicability. The questions were divided into four categories, i.e., “Website Content”, “User Interface”, “Multimedia Design”, and “Practicability”, including a total of 20 questions (Table 1). The following summarizes the results for each category.

- **Website Contents**
  Most students had no doubt about the website contents and thought the virtual coastal ecological environment could help them understand the ecological environment of Hsiangshan Wetland more. The rich contents and related information on the website provided an efficient way for them to know about the coastal ecology of Hsiangshan Wetland.

- **User Interface**
  Most students considered the design of the virtual coastal ecological environment was interesting. The information was easy to browse. After reading the user guide, they were mostly familiar with the operation quickly. Only a few students were not used to the keyboard operation. Through interviews, it was revealed that they were not familiar with the technique of switching 3D visual angles. When using the tour map, some students were not able to locate their positions. The reason was that the virtual coastal ecological scenes were spacious and they could get lost easily when walking inside.

- **Multimedia Design**
  About one-fifth of the students felt that the download speed was a little slow, which could be resulted from the fact that the installation of the plug-in program cost a lot of time. Besides, it was found that a new version of the browser, IE 7.0, would automatically block the ActiveX controls and thus the teacher had to remind the students to unblock it for the plug-in program to be installed successfully.

- **Practicability**
  About three-fourths of the students were positive toward the design of information window popped out after a click on the fiddler crabs. When the students were operating on the system, they would find different fiddler crabs on purpose and pay attention to the ecological film explaining the species. Most students felt the virtual coastal ecological environment could help them understand the natural ecology and increase their learning interest. Only a few students didn’t want to get in contact with more virtual materials. After further interviews, these students indicated that the installation process was time consuming. They suggested the plug-in software should be pre-installed and more interactive games be added to increase their interest in using the system.

5.2 Interview Results
This study conducted interviews with the elementary school’s science teachers to understand their ideas about using the virtual coastal ecological environment for teaching. The interviewees were elementary teachers in Taipei and Hsinchu and the interview process took about an hour. During the interviews, the interviewers first explained the research purpose, interview questions, process of interview and how the results were managed [11]. The teachers were asked to operate the system and answer questions about the virtual ecological environment. Finally, the interview transcripts were written and confirmed by the teachers again.

This study adopted a semi-structured interview approach [12] by setting up an interview outline as a guideline. The following four issues were investigated, i.e., virtual contents and its appeal, multimedia characteristics and integration, learning adaptability, and learning assistance. After interviews, the opinions of the teachers were organized and summarized, possible obstacles that they may encounter were discussed, and their suggestions for improving the system were derived. The following are the results and interpretations obtained based on some teachers’ interview transcripts.

- **Virtual Contents and its Appeal**
  **The researcher:** “Do you feel that the contents of the virtual coastal ecological environment are suitable for teaching applications? Does the design need any improvements?”
  **The teacher:** “Right now, the materials used by elementary school teachers are mainly traditional materials. The virtual reality or multimedia teaching methods can easily catch students’ attention and increase their willingness to learn. In terms of operation, senior teachers or students with less experience in using computers need to spend more time familiarizing with the operation. Therefore, there must be clear instructions about system operation and user interface design for the teaching contents to be effectively delivered to students.”

- **Multimedia Characteristics and Integration**
  **The researcher:** “In terms of multimedia characteristics, is it helpful to use the virtual reality techniques to simulate coastal ecological environment, tidal changes, and wind speed? Are there any needs for improvement?”
  **The teacher:** “Employing multimedia for interaction can easily attract students’ attention toward the learning contents. When designing multimedia materials, one must also consider the meaning of teaching materials behind the design and clearly deliver the knowledge. If the presentation style is close to daily life, perhaps better results can be achieved. The effect of multimedia presentation is after all very limited. Therefore, if the multimedia characteristics can be used to catch students’ attention and increase their interests and, perhaps, give them impressions about the real environments or the motivation to know more and go one step further, then this would be the best result.”

- **Teaching Adaptability**
  **The researcher:** “Do you think it is suitable to apply virtual reality software to science and environmental education? How can we design good virtual reality software and apply it in teaching?”
  **The teacher:** “Software such as the virtual coastal ecological environment can be used as a preparation material for field investigation. In the design of teaching activities,
teachers can give questions and guide students to search for answers in the virtual learning environment. The 3D visual effects may cause students to lose their interest and attention toward traditional textbook learning. Hence, this problem must be accessed and considered as well.”

6. Learning Assistant Tools

The researcher: “Overall, do you think using virtual reality as an assistant tool suits the teaching needs? When you have the related lessons, would you consider using it?”

The teacher: “I personally feel affirmative toward the virtual teaching materials and I am highly willing to apply virtual reality to teaching. When the environmental resources are insufficient, virtual reality becomes a good supplementary material in science education. Before doing field investigations in ecological environments, it provides students with some preliminary concepts of real ecology. For actual applications, the effects may be better if students have hands-on operations. Therefore, having the classes in a computer classroom or planning the lesson in a computer course would be a more feasible teaching approach.”

6. Conclusions

This study developed a web-based virtual coastal ecological environment to display the natural landscapes of Hsiangshan wetland at Hsinchu, Taiwan and its biological species using network and virtual reality technologies. By web programming, this study can also obtain real-time data from Central Weather Bureau to simulate the tidal height and rotating speed of wind turbines at Haishan Fishing Port such that the users can feel the tidal changes and wind speed at Hsinchu coastline area. They can browse the contents and associate field investigations with the design of teaching activities to acquire ecological and coastal knowledge about wetlands and their protection. In the design process, the ecological knowledge of Hsiangshan Wetland, computer skills, and ideas of science education were integrated through discussions and cooperation of experts in various research fields so as to develop a virtual coastal ecological environment that is professional and satisfies the need of science education.

The main goal for developing the virtual coastal ecological environment is for users to learn about the coastal ecology and the related knowledge about environment protection, cultivate the love for nature, protect Hsiangshan Wetland, and take care of our home, Earth. To understand users’ thoughts about the system, this study conducted a user analysis on elementary school students and carried out interviews with science teachers; the results can be used as a reference for future improvement. The results of this study indicated that most students found the contents of the virtual coastal ecological environment interesting and useful. Also, the website enabled them to understand the ecological environment of Hsiangshan Wetland and was helpful in learning natural ecology. The interview results from science teachers were affirmative toward the virtual reality materials and they were willing to apply the materials in teaching.

The use of the virtual coastal ecological environment is not limited to time or space, and can avoid the exhaustion resulted from traveling back and forth to a real location; therefore, the virtual environment provides a convenient network learning space. The computer technology is used to expand the user’s vision; the virtual reality is employed to increase his or her learning interest and motivation; and, finally, through the Internet the educational goals can be achieved.

With highly interactive and 3D visual effects, the web-based virtual coastal ecological environment has the characteristics of distance learning. The users can explore and learn at any place and any time on the Internet, which is very helpful for teaching the ecology about domestic wetland and promoting environmental protection as well.

Acknowledgement

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References

<table>
<thead>
<tr>
<th>Categories</th>
<th>Please read the following questions carefully, and select the number of the answer representing your opinion for each question.</th>
<th>1. Very Agree</th>
<th>2. Agree</th>
<th>3. No Comment</th>
<th>4. Disagree</th>
<th>5. Very Disagree</th>
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<tbody>
<tr>
<td><strong>Website Contents</strong></td>
<td>1. The website provides abundant contents and information related to the coastal ecological environment.</td>
<td>78.6%</td>
<td>21.4%</td>
<td>0%</td>
<td>0%</td>
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<td></td>
<td>2. The contents of the website are correct.</td>
<td>50%</td>
<td>25%</td>
<td>25%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>3. The contents of the website are easy to understand.</td>
<td>51.9%</td>
<td>40.7%</td>
<td>7.4%</td>
<td>0%</td>
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</tr>
<tr>
<td></td>
<td>4. The contents of the website are interesting and educational.</td>
<td>82.1%</td>
<td>7.2%</td>
<td>10.7%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>5. The website can help me understand the ecological environment of the coastal wetlands at Hsiangshan.</td>
<td>88.9%</td>
<td>11.1%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td><strong>User Interface</strong></td>
<td>1. The operation of the virtual coastal ecological environment is easy.</td>
<td>60.7%</td>
<td>25%</td>
<td>10.7%</td>
<td>3.6%</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>2. The virtual coastal ecological environment is lively and interesting.</td>
<td>61.5%</td>
<td>30.8%</td>
<td>7.7%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>3. The texts of webpages are clear and their font sizes are proper.</td>
<td>55.6%</td>
<td>29.6%</td>
<td>11.1%</td>
<td>0%</td>
<td>3.7%</td>
</tr>
<tr>
<td></td>
<td>4. The information on the website is well organized and easy to read.</td>
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<td>23%</td>
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<td>5. The tour map on the website can help me identify my current position.</td>
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<td>17.9%</td>
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<tr>
<td><strong>Multimedia Design</strong></td>
<td>1. The speed to download the system is not too low.</td>
<td>46.4%</td>
<td>14.3%</td>
<td>17.9%</td>
<td>17.9%</td>
<td>3.6%</td>
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<tr>
<td></td>
<td>2. The 3D models and dynamic simulation of crabs are realistic.</td>
<td>60.7%</td>
<td>28.6%</td>
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<td>3. The tidal changes in the virtual scene of Haishan Fishing Port enable me to understand the phenomenon of tides.</td>
<td>64.3%</td>
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<td>14.3%</td>
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<td>4. I can know the wind speed of Hsinchu coastline by observing the rotating wind turbines in the virtual scene of Haishan Fishing Port.</td>
<td>67.9%</td>
<td>21.4%</td>
<td>7.1%</td>
<td>3.6%</td>
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<td>5. Visiting the virtual coastal ecological environment makes me feel like riding a bicycle along the 17 km coastline at Hsinchu.</td>
<td>50%</td>
<td>35.7%</td>
<td>14.3%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td><strong>Practicability</strong></td>
<td>1. Clicking on the crabs in the virtual scene to show introductory movies and pictures can help me understand the features of crabs.</td>
<td>74%</td>
<td>26%</td>
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<td></td>
<td>2. The experience in the virtual coastal ecological environment can help my observation at Hsiangshan wetland in the future.</td>
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<td>21.4%</td>
<td>7.1%</td>
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<td>3. Visiting the virtual coastal ecological environment makes me become more interested in the ecology of Hsiangshan wetland.</td>
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<td>7.1%</td>
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<td>4. I think the virtual coastal ecological environment is helpful in learning natural ecology.</td>
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<td>5. I hope to study more virtual reality teaching materials.</td>
<td>77.8%</td>
<td>11.1%</td>
<td>3.7%</td>
<td>3.7%</td>
<td>3.7%</td>
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