Educational effectiveness of the marine education program using 3D clam model

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アサリ3D 模型を活用した海洋教育プログラムの教育的効果

Hirohisa OGAWA*
小 川 博 久
Nobuhiro OGAWA†
小 川 展 弘

1．Introduction

Being surrounded by the sea, Japan receives a variety of benefits from the sea and lives in a close relationship with it. Oceans account for 97.5% of the water on Earth, support the global environment as the main source of the water cycle, and play a major role in sustaining human lives. Oceans are a source of diverse living organisms, energy, minerals, and other natural resources, and places for leisure activities. However, in recent years, global warming has been reported to have reduced oceanic resources and impacted marine ecosystems. The IPCC report states that climate change is causing sea temperatures and sea levels to rise and seawater to become more acidic(1). Furthermore, the 2023 IPCC Sixth Assessment(2) predicts that these changes will have serious impacts on marine ecosystems and biodiversity, with the potential to reduce the distribution and productivity of fish and shellfish, causing further loss of habitats such as coral reefs and seaweed beds.

According to the Survey of Sea Fisheries Production Statistics by the Ministry of Agriculture, Forestry, and Fisheries(3), Japan's clam catch ranged from 120,000 to 160,000 tons between 1964 and 1986. Since this peak period, the catch has been declining since 1988, and in recent years, there has been a drastic decrease from 2014 to 2020(4). The catch has remained below 5,000 tons since 2020. In addition, tidal clam harvesting is continuously cancelled in many areas famous for clams. Clams are shellfish species used for food and aquaculture in Japan and play an important role in

* 武蔵野大学サステナビリティ研究所非常勤講師
† 東京大学大気海洋研究所

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marine ecosystems. Global warming has seriously impacted marine organisms, including clams, resulting in decreased distribution, productivity, and habitat loss. Clams feed on phytoplankton that filter organic matter from water and purify seawater. They absorb carbon dioxide and store it as calcium carbonate in their shells, contributing to climate change mitigation[(5)]. Clams are shellfish species used for food and aquaculture and provide social value through economic activities such as fishing, fish processing, and food culture. The following educational benefits can be expected from marine education programs that use clams as teaching material:
Through the dissection of clams, we observed and understood how clams adapt to the marine environment and perform their life activities.
Learning about the biodiversity by comparing clams and other animal groups makes it possible to recognize the effects and risks of global warming on clams and consider how it may affect their lives and the industry.

Aiming for the above educational benefits, the marine education program in this study focuses on content related to SDG 14- Life Below Water. SDG 14 is one of 17 sustainable goals termed the “Sustainable Development Goal” and sets specific targets, such as preventing marine pollution and conserving coastal and marine areas by 2030 [(6)]. Practices to promote Education for Sustainable Development (ESD) that contribute to these SDG's in Japan[(7)(8)(9)], and it has been confirmed that concrete experiences can increase research interest in the oceans. We believe that experience-based learning is an important element of marine education[(10)(11)]. We believe that learning regarding clams as living organisms through concrete experiences in science education will serve as a foundation for preserving biodiversity and understanding marine ecology.

Considering this background, the Atmosphere and Ocean Research Institute of the University of Tokyo and the Department of Environmental Systems, Faculty of Engineering, Musashino University, collaborated on the use of 3D models of clams in marine education programs, ESD educational practices, and curriculum development. In this study, we reported the educational effects of a marine education program using a 3D model of a clam in a junior high school science class on learning the functions of clams in the marine ecosystem and environment.

2. Materials and methods

2.1 Clam 3D model

Features of the clam 3D model (Fig. 1)

The 3D model was developed at the University of Tokyo's Atmosphere and Ocean Research Institute. The model was converted to teaching material as a production kit (Fig. 2).

Eighteen sheets of CT data from the clams were combined to form a three-dimensional structure.

The model was simple, lightweight, and durable and was combined with transparent films at regular intervals. The time required to create the 3D model was approximately 15 min.

The transparent film/film and washer were alternately inserted into the shaft and cap so that it was easy for everyone, from elementary school students to adults. The body was created such that the clam can be imagined in three dimensions. The shape of the three-dimensional exterior and the continuous internal structure of the clam could be observed by extracting any one piece of the clam.

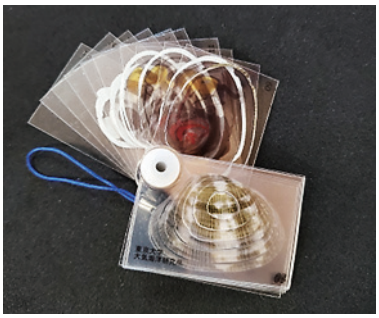

Fig.1 3Dmodel of a clam

Fig.2 3D model making kit

2.2 Creation of an educational program using a 3D model of a clam

The Atmosphere and Ocean Research Institute of the University of Tokyo and the Department of Environmental Systems, Faculty of Engineering, Musashino University (Fig. 3) collaborated on the use of 3D models of fish and shellfish (clams) in marine education programs, ESD educational practices, and curriculum development[7].

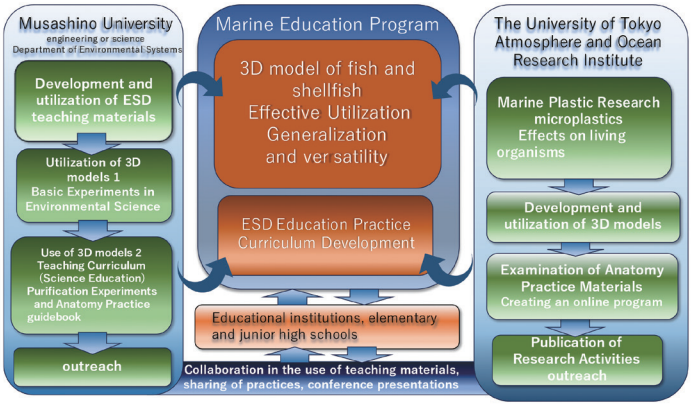

Fig.3 Musashino University-University of Tokyo Marine Education Collaboration

Students who enrolled in the science teaching course at Musashino University learned about the development of the clam 3D model and the environmental issues surrounding it in an online class at the Atmosphere and Ocean Research Institute (Fig. 4.1). In addition, students studied the educational materials and 3D model created for the first-year junior high school science class named “Dissection of Clams” and discussed how to effectively utilize the 3D model and the dissection practice. Furthermore, in anticipation of collaboration in junior high school science, the students discussed lesson plans utilizing the 3D model[12] and teaching methods for the dissection practice of clams (Fig. 4.2).

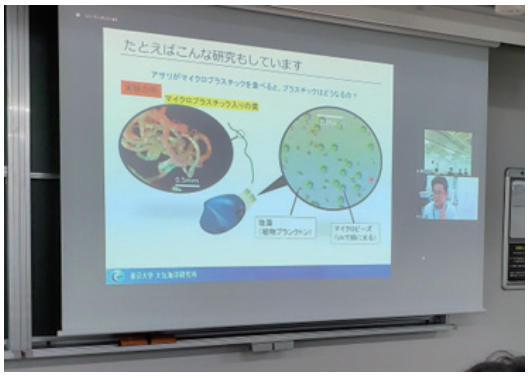

Fig.4.1 Online classes at the University of Tokyo

Fig.4.2 Students examining anatomical methods

2.3 Preparing anatomy practice materials

For the dissection practice, we used anatomical images and diagrams (Fig. 5.1-2) created by the Atmosphere and Ocean Research Institute, which, together with 3D models, are effective materials for understanding clam systems. Images were acquired to determine the function of the clam organs. The water ducts, heart, and gills were discussed as video materials (Fig. 6.1-2). As a result, the students could learn their functions and systems during the practice of dissecting clams. The students' realization that clams are living organisms comes from observing the movement of their hearts. In addition, the video material of the gills was observed using a microscope. The microscopic structure of the gills[13] and the movement of the cilia are important for teaching students to visualize before dissection.

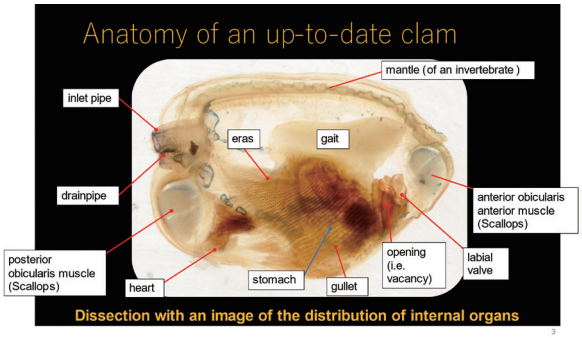

Fig.5.1 Plastination specimen
Anatomical diagram

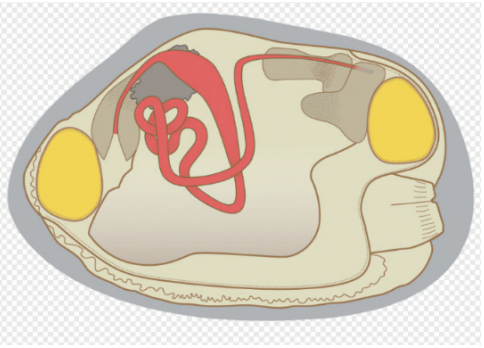

Fig.5.2 Anatomical diagram
created for practical use

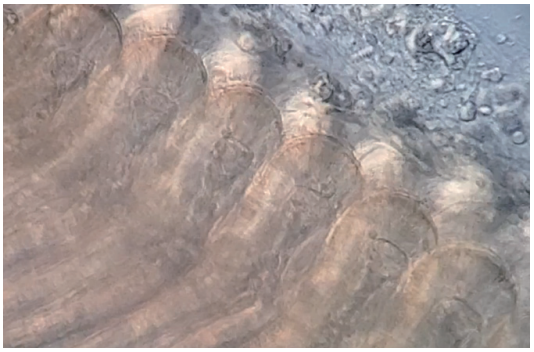

Fig.6.1 Gill video documentation

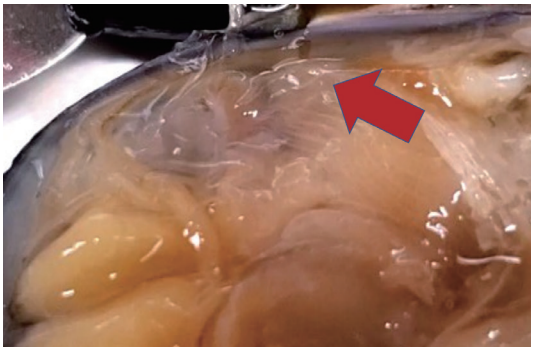

Fig.6.2 Heart of a clam
Document video (arrow)

2.4 Preparation of the Guide to Dissection

Dissection of clams was conducted in science classes. A teaching issue in clam dissection is that when live clams are used, it is difficult for junior high school students to identify the digestive tract. In a collaborative class conducted by the University of Tokyo, on-site science teachers commented that it was difficult to identify clam organs. Therefore, we used clams boiled in water as the teaching material. We then decided that a dissection guide was necessary. As a result, students could check the dissection procedure and actual objects during dissection practice. The "Guide to Dissection" (Fig. 7) was prepared by students enrolled in the science teaching course at Musashino University after studying the teaching methods for the dissection of clams.

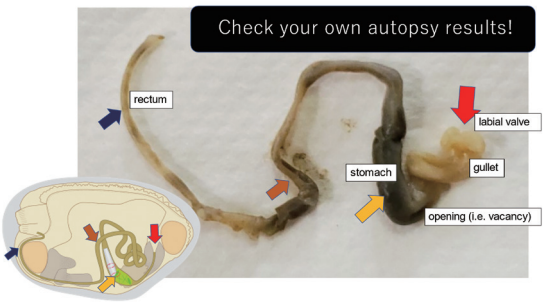

Fig.7 Guide to dissection (excerpt)

2.5 Survey Methodology

(1) Actual condition for junior high school cooperation

We obtained the cooperation of Maisaka Junior High School, located near Lake Hamanako. A famous clam-producing area planned a collaborative lesson on "Anatomy of a Clam," a first-year science class. Hamamatsu Maisaka Junior High School is located in a way that is blessed with nature and stands within walking distance of Lake Hamanako and the ocean.

(2) Preliminary preparation through collaboration with junior high schools

December 2022–May 2023 discussions with junior high schools and preparation of teaching materials for implementation of the marine education program

(3) Date of class　June 28, 2023

(4) Schools cooperating in the survey

Maisaka Junior High School, Hamamatsu City, Shizuoka Prefecture

Students surveyed: 69 students in 1st year (three classes of 50 min each).

(5) Survey Contents

A Google Forms pre and post-questionnaire survey of students was conducted.

Pre-questionnaire survey date: June 22 and 23, 2023

Post-questionnaire survey date: July 4, 2023

Questionnaire Content

i Clams are important to humans.　ii Clams are food.

iii Clams are living organisms.　iv Important to protect these habitats.

Students were asked to respond to the above questions using a four-point scale: agree, agree a little, not agree much, or don't agree at all.

In the post-survey, free-text statements regarding the class were analyzed using text-mining techniques to examine changes in students' attitudes. Text mining was conducted using KHCoder3, free software for quantitative text analysis of text-type data[14][15]. This software allows users to perform various searches and identify frequently occurring words using frequency tables. In addition, multivariate analysis can explore concepts in data by examining groups of words that occur frequently or groups of documents that contain the same words.

2.6 Program content of science collaboration classes

A lesson program was developed as a developmental study of invertebrate observation in　a junior high school science class's first-grade "Animals" unit (Table 1).

The following evaluation criteria were used for class evaluation:

(1) Students were interested in the body characteristics and movements of invertebrates (clams). They were willing to observe and explore them scientifically.

(2) Observing the body structure and movements of the clams in detail and recording

the results appropriately in diagrams and sentences was performed.

(3) From learning about the ecology of clams and the environment of Lake Hamanako, we were thinking about the connection between organisms and the environment in a developmental manner.

Table 1 Main study contents of cooperative classes

Main Learning Activities	Student Activities
1. "Let's learn about clams." Tide-drying and changes in the catch of clams, Food and gastrointestinal tract structure of clams. Body structure and function, clam cleansing action.	○Learn about the feeding habits and habitat of clams Consideration of habitat change based on changes in the catch of clams
2. "Let's make a 3D model of a clam." Let's take a three-dimensional view of the clam's body.	○Confirming the three-dimensional body structure from a 3D model of a clam Practice in dissection of clams
3. "Anatomy of a Clam." Locate the digestive tract (mouth, stomach,rectum, etc.) of the clam.	○Work on dissection with the help of a dissection guide.
4. "Clams and their habitat in Lake Hamanako" No more clams in Lake Hamanako. What is the cause of their quantity reducing to 1/50th of what it was 10 years ago?	○Habitat of clams in Lake Hamanako Learn about the habitat conditions of clams and think about the environment of Lake Hamanako.

3. Results

3.1 Students in Collaborative Classes

(1) "Let's learn about clams"

The students had a relatively large number of natural experiences, almost all involving ebb and tidal flows. They were highly interested in the nature of the region, including Lake Hamanako. Students' recognition that clams are living creatures was evident in their reactions to images of clams (Fig. 8.1).

Fig.8.1 Function of the clam water pipe

(2) "Making a 3D model of a clam"

High interest and willingness to work on the clam 3D model were observed.

However, many students were unable to do

so. Work time was set at 15 min; however, a few students needed assistance with their work (Fig. 8.2).

（3）“Dissection of the clams”

Boiled clams were distributed to each student for the dissection exercise. One live clam was assigned to each treatment group. The students worked with a dissection guide using tweezers to check each organ, particularly the digestive tract of the clam (Fig. 8.3).

（4）“Clams and their habitats in Lake Hamanako”

The students watched a news video [16] on clams in Lake Hamanako.

The students were informed that the catch of clams had decreased drastically to 1/50th of what it was ten years ago. This allowed them to think about changes in clam habitats.

Fig.8.2 A student making a 3Dmodel

Fig.8.3 Students working on dissection

3.2 Results of the Questionnaire Survey

Regarding the results of the questionnaire survey (Fig.9), for the “clams are important” question, the number of students who answered "Agree" after the fact increased from 69.5% in the pre-survey to 82.6% in the post-survey. For the question, "I think clams are food," the number of students who answered "Agree" decreased from 78.0% in the pre-survey to 62.3% in the post-survey. The total of "Agree" and "Agree a little" results was 93.3% in the pre-survey and 71.3% in the post-survey. The questions "I think clams are living creatures" and "It is important to protect the aquatic environment where clams live" received "Agree" with high response rate of almost 95% both before and after the survey.

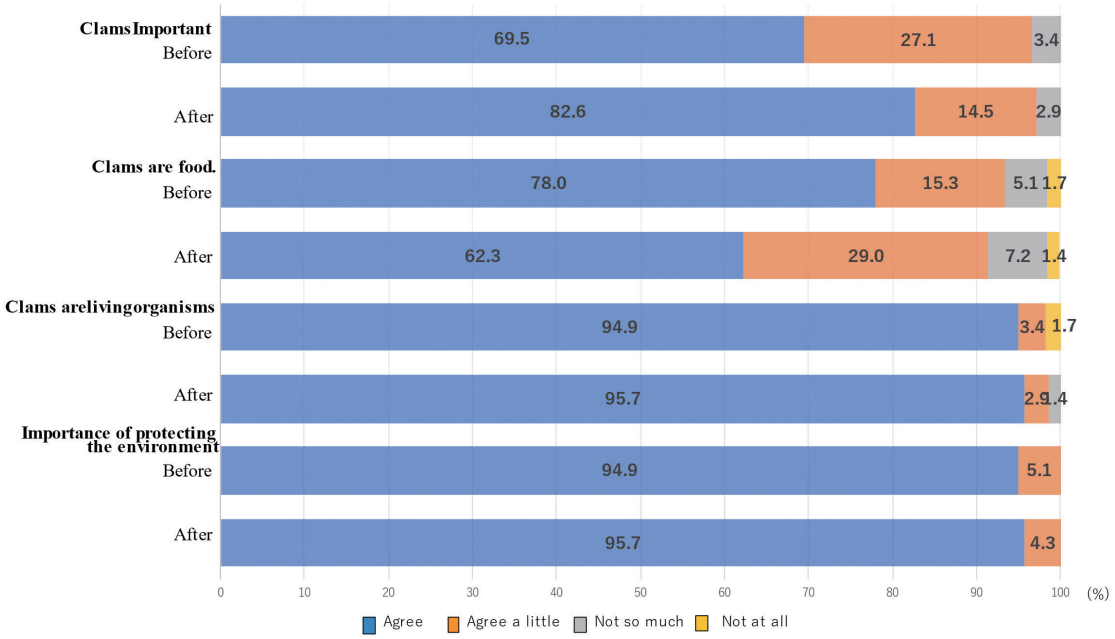

Fig.9 Results of the Questionnaire Survey

3.3 Text Mining Results

Students' free-response statements in the post-survey were analyzed using text mining methods. The top 30 words extracted from impressions were investigated (Table 2). Among the top 15 occurring words, "Clam" was the most frequently occurring word for "Clam," but "Know" and "Decrease" were the next most frequently occurring. "Contents," "Organisms," and "Body" are words related to observation and dissection. Furthermore, "Important," "Environment," "Eat," "Seeing." "Human," and "Protect" characteristically appear in the descriptions of impressions.

Words related to the structure of the body, such as "Heart," "Live," "Mechanism," and "Mouth" appeared in the bottom 15 occurrences. In addition, words related to the local environment, such as "Number," "Lake Hamanako," and "Understood" appeared.
Words such as "Astonishment," "Dissection," and "3D model" emerged in connection with the fabrication and dissection of 3D models.

Table 2 List of Frequently Occurring Words in Free Descriptions in the Post- Survey

Extracted term		Frequency of term usage
In English	In Japanese	
Clam	アサリ	167
know	知る	33
Decrease	減る	26
Contents	中身	20
Organisms	器官	19
Body	体	17
Importance	大切	17
Environment	環境	15
Eat	食べる	13
Seeing	見る	12
Human	人間	12
Make	作る	11
Protect	守る	11
Living thing	生き物	11
Sea	海	10

Extracted term		Frequency of term usage
In English	In Japanese	
Heart	心臓	10
Live	生きる	10
Various	色々	9
Structure	仕組み	8
Fun	楽しい	7
Mouth	口	7
Number	数	7
Lake Hamanako	浜名湖	7
Understood	分かる	7
Surprise	びっくり	6
Dissection	解剖	6
Catch	取れる	6
3D model	3D 模型	5
Feel	感じ	5
Pattern	模様	5

3.4 Co-occurrence network results

A co-occurrence network is a diagrammatic representation of the relationships between words that appear together in a document (Fig. 10). By visualizing the relationships between words, it is possible to understand frequently occurring expressions and explore concepts contained in the text. Darker lines connecting words indicate stronger associations.

From the co-occurrence network diagram, "Clam," "Know," "Decrease," "Lake Hamanako," "Body," and "Structure" co-occur. In addition, the three keywords "Environment," "Protect," and "Sea" co-occur, with "Environment," and "Protect," having a strong correlation. Three keywords, "Living thing," "Human," and "Importance" co-occur in relation to relationships with living creatures. Regarding the contents of the clam lesson, "Contents," "Seeing," "Surprise," and "Feeling" were co-occurring keywords. For dissection, "3D model," "Internal organs," "Dissection," "Make," and "Fun" co-occurred.
When the characteristic words "Environment" and "Protect" were searched for descriptions of student impressions, the students described the following:

Because the "Environment" is changing, I want to improve it in the future because it is decreasing.

I thought about the "Environment" and wanted to help clams. I was reminded that clams are necessary to " Protect " the ocean. Clams are important to humans, and we should " Protect" the environment in which they live.

When we searched for descriptions of students' impressions based on the characteristic words "3D model" and "Fun," students described the following:

The "3D model" was "Fun" to make because it showed in detail the location of the clam's internal organs.

The "3D model" was made to show how the inside of a clam is made, although the location of the organs was not clear in the dissection.

The students made a "3D model" of the clam and were able to understand what was inside the clam's body. Moreover, it was "Fun" to make it. Additionally, it was surprising to use and examine the "3D model" of a clam.

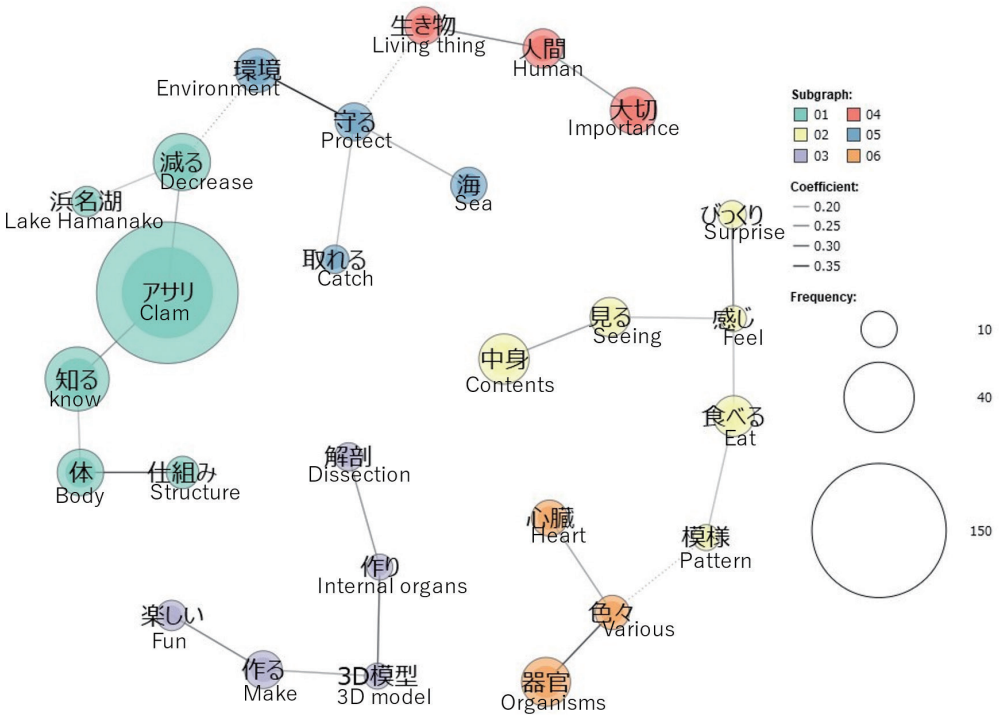

Fig.10 Co-occurrence network diagram (top 30 words) created from Student Comments

4. Discussion

Regarding the use of the clam 3D model, characteristic words such as "3D model," "Dissection," "Make," and "Fun" co-occurred. We believe that the clam 3D model is suitable for practical dissection. One student said, “It feels like dissection” when making the 3D model.

In the post-survey for the question, “Clams are important to humans,” students who answered "Agree" had a higher occurrence rate of keywords related to the clam's body,

such as "Organisms," "Heart" and "Contents," suggesting that their awareness of clams as living creatures is enhanced by their knowledge of how their bodies work and function.

In the post-survey, students who responded "Don't agree much" to the question "I think clams are food" had a higher occurrence of keywords related to the clam's body, increasing their perception of the clam being a creature and decreasing their perception of it as food. Because clams are a familiar food, the students highly perceived clams as food before the study. However, after learning the body structure and mechanisms of clams, their perception of clams as living organisms increased.

In the results of the use of the clam 3D model, the text analysis showed that characteristic words such as "3D model," "Make," "Fun," and "Dissection" co-occurred and emerged. Students viewed the creation of the clam 3D model positively, suggesting that its educational effect on dissection practices was recognized.

Characteristic words such as "Environment" and "Protect" suggest that students have turned their attention to the local natural environment concerning clams and have become aware of the connection between humans and the natural environment. A few of the students' comments indicated that they were beginning to develop an awareness of environmental conservation.

５．Conclusion

The use of a 3D model of a clam was effective in generating interest in the clam's body structure and functions and in enabling students to visualize the positional relationship of the clam's organs and other parts in three dimensions before dissection practice, suggesting the effectiveness of the use of 3D models.

The number of students who think that clams are important to humans increased as they learned about the structure and mechanisms of clam bodies, strengthening their recognition of clams as living creatures and their functions.

The educational program resulted in a change in the perception of students towards clams and created awareness about the conservation of the natural environment in the region.

In the future, we believe that the educational effectiveness of dissecting clams may vary depending on the students' actual conditions. For future research, we would like to verify the improvement and educational effectiveness of clam teaching materials. We would then like to recruit junior high schools to cooperate with us on a large scale and verify the effectiveness of the educational materials and programs.

[Acknowledgments]

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