

Evaluation of the "Simulator for the Worsening of Bioaccumulation" Linking the Marine Environment and Daily Life

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Abstract: This study developed a simulator to help students learn about the worsening of bioaccumulation caused by microplastics (MPs) intervention while linking the marine environment and daily life and evaluated its effectiveness. Using the simulator, sixth-grade science classes that linked bioaccumulation to their study of the food chain provided a scientific explanation of how MPs intervention can worsen bioaccumulation. Analyzing the scientific explanations in the "students' understanding" revealed that of the 50 students, 33 students [66%] achieved a perfect score, which means that most of the students were able to explain scientifically. In the "students' usability," 11 questions were asked, and all questions were answered in the affirmative, with an average score of 3 or higher. As a result of the transfer test, 27 students [54%] could answer correctly. Furthermore, follow-up interviews revealed that the simulator helped students scientifically understand the principles of worsening of bioaccumulation owing to the intervention of MPs by using the properties of MPs and the mechanism of bioaccumulation, while linking the marine environment with daily life.

Keywords: Bioaccumulation, environment, simulator, scientific understanding

1. Introduction

In recent years, food poisoning caused by worsening bioaccumulation of microplastics (MPs) has become a problem. MPs adsorb large amounts of harmful chemicals (harmful substances), promoting bioaccumulation. To prevent food poisoning, scientifically considering food safety is significant, while being aware of the relationship between everyday actions such as handling plastic products and environmental issues.

To foster this ability, linking the marine environment with daily life and acquiring a scientific understanding of the properties of MPs and the worsening of bioaccumulation caused by their involvement (e.g., Chang et al., 2019; Matsuyama et al., 2023) is necessary using simulators by following instructions. Matsuyama et al. (2024) developed simulators that could compare bioaccumulation with and without MPs. The simulators helped students understand that "bioaccumulation progresses further when MPs are present," however, they were ineffective in helping them understand the adsorption properties of MPs and the connection between the marine environment and daily life.

Therefore, in this study, we developed a simulator for the worsening of bioaccumulation, linking the marine environment to daily life, and evaluated its effectiveness.

2. Features of the Simulator and Its Use

Figure 1 (left) presents the home screen of the simulator. In this simulator, a possible everyday situation is set: "Plastic products that children use on a daily basis, such as plastic bottles

(PET), food trays (PS), and folding umbrellas (PA), are dumped into the ocean." Students can acquire a greater sense of ownership and understand the phenomenon that "any plastic product dumped will lead to bioaccumulation."

This simulator was introduced in a science class (total 135 minutes) for 50 sixth-graders learning about food chains and bioaccumulation. Figure 1 (right) presents the screen during the simulation. In this class, the students focused on the marine food chain for four creatures: tuna, mackerel, sardine, and plankton. In Scene 1, students selected a plastic product and then simulated bioaccumulation among tuna, mackerel, sardine, and plankton by comparing the amount of harmful substances adsorbed by the MPs of each plastic product and the amount of harmful substances taken up by the tuna. In Scene 2, they scientifically explained the worsening of bioaccumulation by MPs based on simulation results.

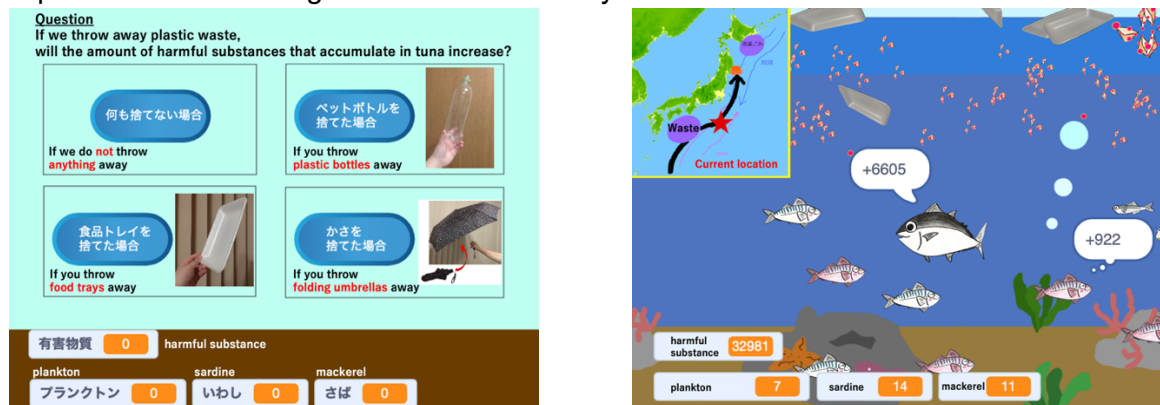


Figure 1. The Screens of Simulators, Home (left) and During Simulation (right)

3. Analysis

Fifty sixth-grade elementary school students participated in the analysis. The survey of "students' understanding" was conducted by analyzing the explanatory text in Scene 2 regarding the worsening of bioaccumulation owing to the intervention of MPs. It was scored out of 2 points for "whether the property of MPs, in which MPs adsorb large amounts of harmful substances, is correctly explained (Perspective 1, 1 point)" and "whether the mechanism of bioaccumulation, in which harmful substances in the body of a prey organism are transferred to the body of the predator, is correctly explained (Perspective 2, 1 point)."

The survey of "students' usability" comprised 11 questions, and the students answered these questions on a 4-point scale. "Applies" was scored as 4 points, "somewhat applies" as 3 points, "does not really apply" as 2 points, and "does not apply" as 1 point. A transfer test was administered to Questions 8–11 (Table 1) to measure the understanding of worsening. In addition, follow-up interviews were conducted with 15 students. The learning effects of the simulator were analyzed, including whether it supported active interactions with the marine environment and connections to daily life.

4. Results and Discussion

Regarding "students' understanding," of the 50 students 33 students [66%] scored 2 points, 16 students [32%] scored 1 point, and the remaining 1 student [2%] scored 0 points. Through the simulation, most students were able to scientifically explain the worsening of bioaccumulation owing to the intervention of MPs using their knowledge of the properties of MPs and the mechanism of bioaccumulation.

Table 1 presents the results for "students' usability." For all questions, the average score was 3 or higher, indicating a positive response. As a result of the transfer test, 27 students [54%] could answer correctly, and approximately half of the students understood that MPs can cause the worsening in different food webs. In follow-up interviews, the following comments were made:

S1: "As I could compare not only the presence or absence of MPs, but also the type of MPs, I could consider the differences in the amount of harmful substances adsorbed."

S2: "As bioaccumulation progresses even more, I realized that littering plastic bottles and other items is not good after all."

Our simulator was effective in promoting an understanding of the properties of MPs and in raising awareness of the relationship between the marine environment and daily life, and it helped students scientifically understand the principles of worsening bioaccumulation by MPs.

Table 1. *Contents, Mean, and Standard Deviation of the Questionnaire on "students' usability"*

| Question | Mean | S.D. |
|--|------|------|
| Q1. The simulator was easy to use. | 3.78 | 0.46 |
| Q2. By using the simulator, I was able to confirm my prediction on the question, "Will dumping plastic waste into the ocean increase the amount of harmful substances that accumulate in tuna?" | 3.76 | 0.43 |
| Q3. By using the simulator, I was able to think about the types of creatures that tuna eat, while also paying attention to the amount of harmful substances and seeing how they are transferred. | 3.34 | 0.89 |
| Q4. By using the simulator, I was able to think about the number of creatures that tuna eat, while also paying attention to the amount of harmful substances and seeing how they are transferred. | 3.26 | 0.91 |
| Q5. By using the simulator, I was able to think about the colors of creatures that the tuna eat, while also paying attention to the amount of harmful substances and seeing how they are transferred. | 3.50 | 0.73 |
| Q6. The amount of harmful substances was always displayed in the simulator, making it easy to see how much of the harmful substances had accumulated inside the organisms. | 3.62 | 0.69 |
| Q7. When a creature in the simulator ate another creature, the amount of harmful substances was displayed, such as "+10," making it easy to understand how harmful substances are transferred up the food chain. | 3.62 | 0.63 |
| Q8. By using the simulator, I was able to understand the bioaccumulation of harmful substances while using my knowledge of the food chain. | 3.48 | 0.70 |
| Q9. By using the simulator, I was able to understand that the presence of microplastics increases the amount of harmful substances that can be absorbed into a creature's body at one time. | 3.62 | 0.75 |
| Q10. By using the simulator, I was able to confirm that "microplastics promote bioaccumulation more than when they are not present." | 3.44 | 0.78 |
| Q11. By using the simulator, I was able to understand that the rate at which harmful substances bioaccumulate varies depending on the type of plastic. | 3.50 | 0.73 |

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