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Evaluation of Simulators to Promote the Understanding of Bioaccumulation among Elementary School Students

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Abstract: This study introduced four simulators developed by Matsuyama et al. (2023) into sixth-grade science classes to educate students about bioaccumulation of pufferfish toxin. The simulators helped students understand how the concentration of pufferfish toxin increases as predators approach the top of the food chain. Results of a survey of “students' usability” indicated that all 12 of the questions received a positive rating. In "students’ understanding," the number of creatures that students thought would be affected by DDT (dichlorodiphenyltrichloroethane) bioaccumulation increased in part pre- and post- transfer test. Particularly, the answers of aquatic creatures showed a significant improvement, and it was found that the simulators helped students understand "the food chain and bioaccumulation in the water."

Keywords: Computer Simulation, Scratch, Food Chain, Bioaccumulation

1. Introduction

Bioaccumulation, which is closely related to food issues, is a problem that should be solved by using the knowledge of the food chain learned in elementary school. One bioaccumulation example is pufferfish toxin which is unnoticeable, complex, pervasive, and long-term phenomenon. Thus, directly observing or capturing its entirety is difficult (Itoi et al., 2015). Nonetheless, simulation supports students understanding by simplifying the events and adjusting scale and period of time. (Chang et al., 2019; Shingai et al., 2020). Furthermore, incorporating game elements and scaffolding into the simulation encourages students’ deep exploration (Kukkonen et al., 2014). However, no simulators have been developed in Japanese elementary schools to learn the food chain. This study introduced the simulators for elementary school students to examine the bioaccumulation of pufferfish toxin. The simulator program comprises "Scratch,” which is a teaching tool that can easily be used in various classroom settings, and they were loaded and run locally.

This study aimed to clarify the effectiveness of the simulators for learning bioaccumulation by introducing them to sixth-grade science classes and surveying students' usability and understanding of the simulators.

2. Features of the Simulators and Their Use

Four types of simulators (A, B, C, D) were introduced in the science class "connections between creatures" for 43 sixth-grade students. The simulator-based class comprised two hours wherein students are educated about the food chain and bioaccumulation in five creatures, including pufferfish, crabs, starfish, clams, and marine bacteria.

Figure 1 presents the screens of Simulators. Simulator A in Fig. 1 (left) helped the students understand the relationship between the puffer fish as a top predator and the food

chain. Clicking on a button with the creature's name allows the student to move it freely using arrow keys, enabling students to examine the "eat–eaten" relationship among the five creatures. Thereafter, using Simulators B and C, the students learned that all the toxins possessed by the prey were absorbed by the predator. Simulator D in Fig. 1 (right) helped the students understand that "the accumulation of poison depends on what and how much the predator preys on, and that the amount of toxins concentration increases as the creature approaches the top of the food chain" with classifying the amount of toxins by creature type.

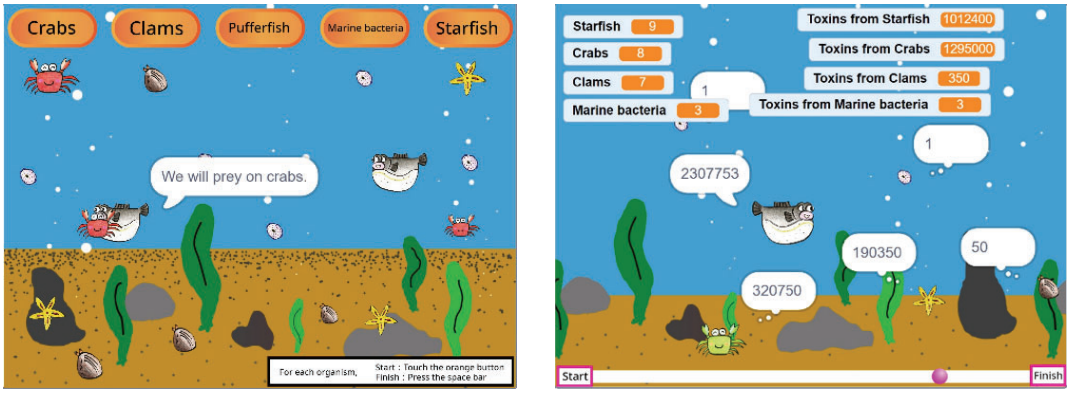

Figure 1. The Screens of Simulators A (left) and D (right)

3. Analysis

The analysis included 43 sixth-grade students. The survey on "students' usability" was conducted with a total of 12 questions, which were answered using a four-point scale: 1 for "not applicable," 2 for "somewhat not applicable," 3 for "somewhat agree," and 4 for "agree." For all questionnaires, the mean and standard deviation were calculated.

In the test concerning "students' understanding," transfer tests were performed. The students were asked to answer nine items, such as lake water, underwater, and terrestrial creatures, assuming the range of DDT's exposure influence. Between the pre- and post-test, the total number of responses for each student was analyzed by Wilcoxon's signed rank test, whereas the number of students in each answer item was analyzed by the McNemar test.

4. Results and Discussion

Table 1 presents the results of "students' usability." For all questions, the average score was 3 points or more (more than a majority of positive opinions). This revealed that all four types of simulators were easy for students to use.

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

Questions	Mean	S.D.
(1) The simulator was easy to use.	3.79	0.41
(2) When the creatures in the simulator ate other creatures, a sound reverberated, making it easy to identify which creatures to pay attention to.	3.44	0.73
(3) When the creatures in the simulator ate other creatures, the amount of poison was displayed, making it easy to identify which creatures I must pay attention to.	3.84	0.43
(4) When the creatures in the simulator ate other creatures, the color of the creatures changed, making it easy to identify which creatures to notice.	3.63	0.72
(5) By moving the creatures in the simulator freely, I was able to confirm the mechanism of the food chain while learning independently.	3.53	0.66
(6) By using the simulator, I learned how invisible things, such as poison in living creatures, are transferred.	3.77	0.42
(7) By using the simulator, I was able to consider the circumstance in its entirety and gain a broad perspective.	3.58	0.58

(8) By using the simulator, I was able to consider what was occurring for an extended period of time while capturing a series of situations.	3.37	0.72
(9) By using the simulator, I was able to observe from various perspectives what is happening in difficult-to-observe environments, such as in the sea.	3.47	0.58
(10) While operating the simulator, I learned the preys and predators of all five creatures (pufferfish, crab, starfish, clam, and marine bacterium).	3.93	0.25
(11) While operating the simulator, I learned how pufferfish poison accumulates in its body from my knowledge of the food chain mechanism.	3.72	0.50
(12) By operating the simulator, I learned that poison is transferred from the body of the being eaten-creature to the body of the eating-creature through the "eat–eaten" relationship.	3.74	0.44

Before and after learning, the overall number of responses that the students believed included DDT tended to increase (Z=−1.849, p<.10). Figure 2 exhibits the number of students who were able to answer all the nine items. The findings demonstrate that the number of students who could answer only for lake shellfish (p<.01) and lake plankton (very small creatures) (p<.05) significantly increased. Thus, it can be inferred that the "food chain and bioaccumulation in water" expressed in the simulators improved students' understand of bioaccumulation.

In the future, we plan to analyze children's decision making using their knowledge of bioaccumulation to evaluate the effectiveness of the simulator. In addition, differences in effectiveness between using and not using the simulator need to be examined.

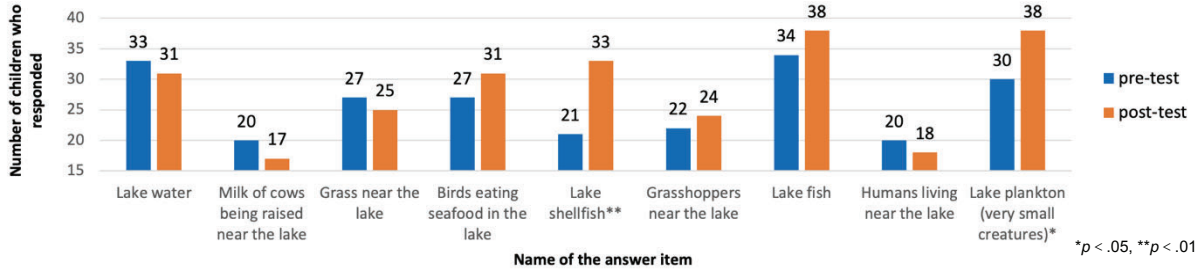

Figure 2. Change in the number of students who responded through learning

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