黒潮圏科学（Kuroshio Science），９－２，96-106, 2016

Research Paper

Evaluation of materials on the curriculum theme “How can water striders float and stride on the water surface?” as an effective experimental teaching material in compulsory schools

Mitsuru Nakajo[1], Toshiki Tamura[2], Shinya Maihara[2], Kazuo Miyoshi[3], Fumiko Kojima[4], Mika Yokota[2], Tetsuo Harada[*2]

[1)] Laboratory of Science Education[1], Faculty of Education, Kochi University

[2)] Laboratory of Environmental Physiology, Faculty of Education, Kochi University, 2-5-1 Akebono-cho, Kochi 780-8520, Japan

[3)] Junior High School affiliated to Faculty of Education, Kochi University

[4)] Elementary School affiliated to Faculty of Education, Kochi University

Abstract

Efficiency of teaching materials of the curriculum theme “How can water striders float and stride on the water surface?” was evaluated in science lessons of elementary and junior high schools. Three major answers are possible to the question of the thema: (1) water striders are very light and have long middle and hind legs; (2) they have numerous fine hairs on their legs; and (3) they extract oil from the tarsus of their legs and put it on the surface of their legs. Putting the detergent into water where water striders are striding causes them to sink into the water. This experiment is effective in some extent for teaching both elementary and junior high school students that maintaining surface tension of water around legs is critical for their floating on water bodies with supporting by oil among the numerous and fine hairs on legs.

Key words: *Water striders, floating on water, surface tension, oil excretion, numerous hairs on legs*

Introduction

In Japanese compulsory education, it is difficult to incorporate fruitful results of current science research into science text books. When Japanese children are asked to give examples of animals, they usually will not answer with invertebrates such as insects, but with mammals such as cats, horses and dogs. Although insects included in the class “Hexapoda or Insecta” make up 70-75% of all animal species, Japanese children know little about ecological and other aspects of insects (Stork *et al*., 2015). *Drosophila* can be a model for introducing insects into the educational scene. Ranganath & Tanuja (1999) argued that *Drosophila* is appropriate to use in materials for teaching genetics in high school and in undergraduate biological courses in colleges and universities. Mathews *et al* (1997) discussed that insects can offer a vast array of teaching opportunities for precollege students. Teachers need to know the basic and biological and/or entomological knowledge in order to use insects successfully in their curricula, and entomologists can take on the role of providing the basics on entomological issues.

As a specific and unique example of introduction of insects into an applied scenario, Dadour *et al* (2001) showed how flies that help in decomposition can become tools for investigation by using them in small animal decomposition trials in the scene of the crime (SOC) and homicide investigations and to educate police and those involved in the judiciary system in the world of forensic entomology.

Received 5 March 2015; Accepted 12 February 2016

*Corresponding author: E-mail, haratets@kochi-u.ac.jp

Currently, these basics in entomology are not sufficiently introduced in compulsory education in Japan. New science information relevant to current science scenarios may be incorporated into science education as new and exciting teaching materials.

Water striders, which belong to the family Gerridae of the order Heteroptera are familiar organisms for children and have been taught as an important member to be introduced into biotopes in most cases (Ito *et al*. 2003, Hirose 2005). Water striders have much larger bodies than Drosophila and very easy to be treated and manipulated by children.

Water striders could be used for appropriate teaching materials for physics theme as "How can some things float on water surface?". In other words, many children may be curiously attracted to the question of "How can water striders float on water?". The following three answers are possible to this question (Cheng 1985, Hu *et al*. 2003, Andersen & Cheng 2004, Dickinson 2004, Gao & Jiang 2004, Bush & Hu 2006, 2010, Zelkowitz 2008, Hu *et al*. 2010, Ji *et al*. 2012): (1) water striders are very light and have long middle and hind legs; (2) they have numerous fine hairs on their legs; and (3) they secrete oil from the tarsus of their legs and put it on the surface of their legs. All answers link to the reduction of the pressure per unit attachment area of water surface to the outside surface of the numerous hairs, and second and third answers relate with surface tension of the water layer around the legs. To teach the first point of three answers, artificial "water strider" robots made of steel wires could be introduced, as some nominated issues for teaching materials (Song *et al*. 2006, Song & Sitti 2007).

Although water striders have been introduced in the Japanese Educational scenes (Takenaka *et al*. 2009), there have been no studies on the efficiency of water striders as a teaching material based on students' answers before and after the classes.

The government guideline for teaching natural sciences in elementary school (the Ministry of Education, Culture, Sports, Science and Technology, 2010a), indicates observation of the nature familiar to children as teaching contents for the third grade, to understand "organisms live under the relationship with the surrounding environments". The guideline also shows the contents on "organisms and their environment" for the sixth grade students. The guideline of junior high school (the Ministry of Education, Culture, Sports, Science and Technology, 2010b) shows a content to teach "morphs and function in animals". These three contents are directly related to an important issue for teaching that "Students can understand the mechanisms of water striders to float on the water surfaces". Another important issue as a new teaching material is that "Whether this material can promote the curiosity and scientific interest to insects or organisms familiar to children".

This study tries to evaluate whether these two important issues for teaching can be achieved by using the teaching material on "How can water striders float on water?". This study evaluates the educational efficiency of the living water striders and the electro-microscopy pictures of the legs as teaching materials. These evaluations were performed by using epidemiological methodology. The educational impact of this teaching material was evaluated by testing its use in actual science lessons in elementary and junior high schools.

Participants and Methods

Teaching materials

Both living adult water striders, *Aquarius paludum* (Fabricius) (Fig. 1) and scanning electro-microscope pictures (Figs. 2, 3) were used as teaching materials. The living water striders were used for the observation of legs attached to water film when floating (Fig. 4) and an experiment entitled "Can water striders continue to float on water film when a droplet of detergent was put to the file?". These electro-microscope pictures were used as the information resources for thinking about why water striders sink after the detergent was put onto the water film.

Guide line on the science lesson and questionnaire studies before and after the lesson

A science lesson entitled "The floating mechanism of water striders" was conducted by two persons (one for elementary, another for junior high school) of the authors (Tables 1, 2). The teachers gave the lesson to a grade 6 (aged 11-12 yrs) classes in the affiliated elementary school and to grade 8 (13-14 yrs) classes in the affiliated

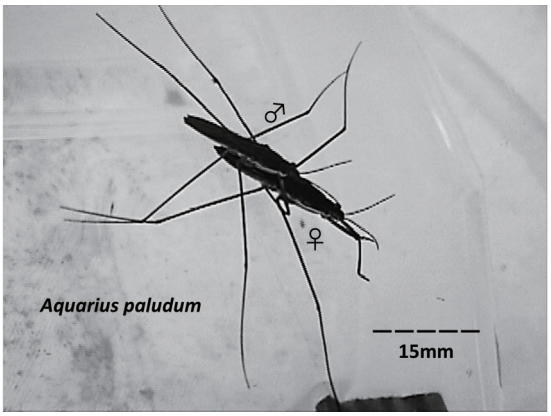

Fig. 1.Adult water striders, *Aquarius paludum* in tandem (female mounted by male) which is the typical posture seen during the reproductive season. (Photo by T. Harada)

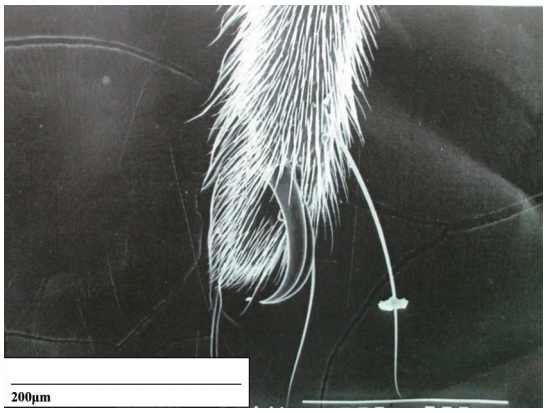

Fig. 2 Teaching material used in the practical science lesson. It shows the scanning electronic microscope (SEM) photo of the apical part of the hind leg of a water strider that is filled with numerous fine hairs and hocks to catch the water surface and two longer mechanical sensory hairs to detect water vibration.(Photo by Harada et al.)

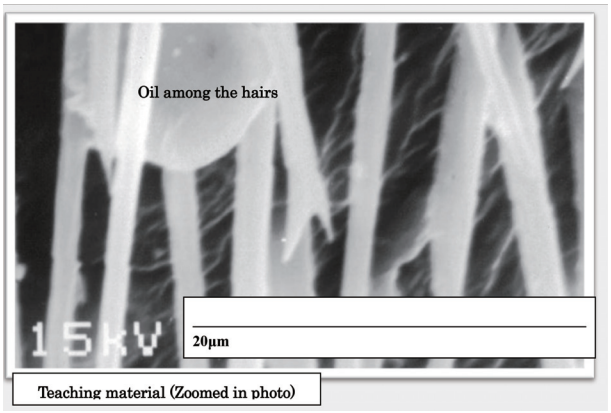

Fig. 3. Teaching material used in the practical science lesson. It shows the scanning electronic microscope (SEM) photo of the skin of the mid leg of a water strider that is filled with numerous fine hairs and keeps a white oil sphere on the bases of hairs.(Photo by Harada et al.)

Fig.4. One scene of a practical science lesson in which five elementary school students observe a water strider, *Aquarius paludum* on the water surface of a transparent round-shaped aquarium. (Taken by T. Harada)

junior high school in the science experimental room for practical training in each school. The same lesson was given to both schools:160, 40 x 4 classes. of elementary school students and 132. 32-35 x 4 classes, junior high school students in October or November, 2007. Students formed seven or eight small groups of 5-6 students to conduct practical experiments during the lesson (Fig. 4). Teaching material on the floating mechanism of water striders were constructed (Figs.1, 2; 3, 5, 6), and was used in the lesson. A questionnaire including a question on understanding about "How can water striders float on water surface?" was administrated before and after the class. Answers to the questionnaire given before the class were compared to those given after the class. The questionnaire data were statistically analyzed with χ^2-test and Wilcoxon-test.

Contents of science lesson

Main contents of this lesson are "observation of how legs of water striders are attached to the water film" and "experiment of what goes on floating water striders when a droplet of detergents is put onto the water film".

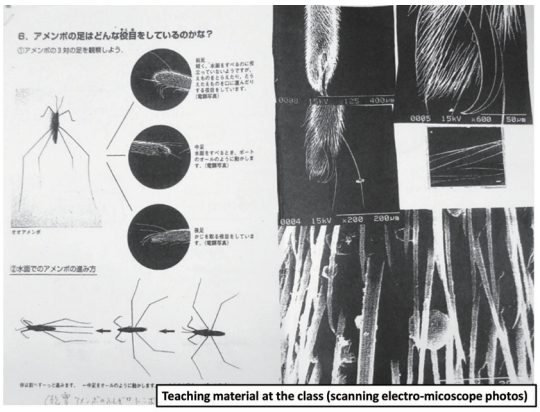

Fig.5. **Teaching material used in the science practical lesson.** It shows the morphological characteristics of the mid and hind legs which are very long and have numerous fine hairs that holds oil on the base. (Photos on the right side: Harada et al.,: Left half was from p. 17 of Inui, 2000)

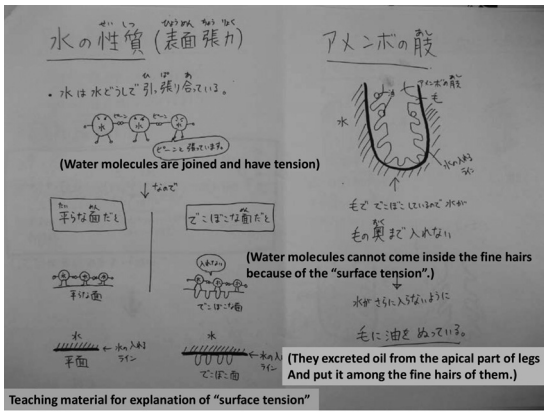

Fig.6. **Explanation sheet for understanding surface tension by children.**

Table 1: Schematic presentation of a practical science lesson (45 or 50 min.)

"How do water striders float on the water surface?"

Affiliated elementary school:	6th grade 1 class (11-12 yrs)
Affiliated junior high school:	2nd grade 4 classes (13-14 yrs)

Questionnaires before and after the practical lesson

About 200 students participated in the practical science lesson.

Common summary of the class (elementary school)

1 (0-5 min.): **Questions on water striders**
(Habitats?, color and morph?, food?)

2 (5-35min.): **A. Observation of water striders on water surface**

B. **Observation of legs on water surface**

C. **Explanation of "how they can float on water surface"**

1) Photograph of legs by SEM (scanning electro-microscope)
2) Explanation of "surface tension of water surface"
3) Observation of oils among the fine hairs on legs (SEM photo)
4) Integrated explanation of how they can float on water surface

D. **Experiment: "How do water striders on water surface behave if we put detergent into the water?"**

E. **Question on "the reason why they sink due to the detergent" and explanation.**

1) Weakening of surface tension of water surface
2) Removal of oils among the fine hairs on the legs

3: (35-40min.): **Pollution of rivers by detergent and other chemicals and limitation in habitats for water striders**
Protection of natural habitats for natural organisms from several chemicals is needed.

Table 2-1. Planning and abstract of the science class "How can water striders float on water?"

Time table	Planning of class	Key points for teaching	Abstract of class
0-15 (min)	Questionnaire administered Questions on water striders to pupils: "Do you know about waterstriders? Have you seen them?" "Answers by several pupils" "What do you think about morphs of water striders?" "Where have you seen water striders living?" "Again answers from several pupils" Explanation by teacher on habitat (ponds, lake, small water pool, river,water way etc) of water striders.	Teacher asks pupils on their relationship with water striders, and make them interested in water striders. Teacher explains shortly life history of water striders to pupils, showing several photos of water striders on water bodies.	Questionnaire administered (0-10 min) "Have you seen water striders?" "Where have you seen water striders living?" Answers: ponds in garden. paddy fields, small water pool, river, swimming pool. "What do you think about morphs and behavior of water striders?" Answers: Flying, carnivorous, insect six legs, four legs.
16-35 min	Observation of water striders on water in round-shaped transparent aquarium (diameter:30cm, height: 15cm) and picking it up and smelling it. "Water striders excrete a scent, because they are kinds of "bugs": Heteroptera. Let's pick it up and smell it!" "How do you smell it? It is called "Amembo" (Ame means sweet candy, bo means Boy in Japanese), because it smells like a sweet candy." "Which part of the legs of water striders are attached to water surface?" "Can you see that long and distal part of the legs are attached to it?" "Can you observe the attached part slightly become hollow on the water surface?""How do water striders float on water body?" Teacher shows the photos of legs taken with Scanning Electro micro-Scope (SEM) to the pupils." You can see that leg surface is filled with fine and numerous hairs which make water molecules out of hairs with surface tension.""Surface tension can be explained the power to make the surface area smallest. " "You can see that oil deposits are among the fine hairs in the SEM photo."	The pupils observe water striders float on water bodies in the round-shaped aquaria. The pupils can find out that the leg part attached to water surface becomes hollow.	Shall we observe the water striders are floating on water surface? Each member of 5 or 6 groups which consist of 5 or 6 pupils observed water striders and picked up them by hands. [It smells like orange.] Then teacher moved onto the explanation of how to float on water surface. First, the fine and numerous hairs on leg surface and the existence of oil-deposits were explained with photos of legs with taken by SEM. "Water striders can float on water using a physical characteristic of water, the "surface tension". Have you heard the word "surface tension?" [No answers by the pupils] "If glass is filled with water over the upper edge, the water became heaped up without overflowing, because molecules of water pull against each other. Water striders can float on water because of surface tension of water molecules. Waters directly attach the smooth surface of the legs if they have no hairs. However, water molecules cannot come-in among rough and fine hairs because of surface tension.

(This table continued to the next page)

Table 2-2. Planning and abstract of the science class "How can water striders float on water?"

Time table	Planning of class	Key points for teaching	Abstract of class
15-35 min	"Oils among the leg-hairs can help the water striders float on water, because oil repels water." "The reason why water striders can float on water body is that the leg surface is extremely bumpy and have oils among the fine leg-hairs." "In some cases, water striders cannot float but sink into water. In what kind of occasions do you think about such trouble occurs?" Pupils answer the question, then ask another question: "How do water striders floating on water behave when washingagents are put into water bodies?" Then the pupils put washing agents into water bodies, and observe the response of water striders. "Why do water striders sink into water?" Explanation of how they are drown in water because of washing agent. 1. Diminishing of surface tension in washing agent solute 2. Removal of oils among the fine leg-hairs due to washing agents.	The pupils can see water striders are sinking in the water body including washing agent.	Moreover, oil droplets among the hairs make the surface tension of waters greater because oils repel water. The teacher accessed to each group and said, "Did you find out that the legs push- the water surface and make a follow there? The pupils put a droplet of washing agents into the aquarium where water striders float on water body and observed them to be drown in the water. The teacher used the teaching materials and explained how water striders were drown. "Washing agents acted as a surfactant and reduced the power of surface tension of waters and moreover jointed both water molecules and oils, and water molecules came among the fine leg hairs. Because of these reasons, legs sunk into the water."
Summary of the class (36-40min)	"If great amount of washing agents derived from general populations are flown into river, water striders can not survive there because there are drowned. Fortunately, many rivers or water ways are available for water striders to live. We should conserve such available habitat of water striders."	"When washing agents from common population are flown into a river, there are possibilities for water striders to be drown in the river. If you wash something using washing agent, please think about water striders and reduce the amount of that."	

Process of science lesson

Observation and explanation

After taking time (5min.) for the observation of water striders which are floating on the water body of the round shaped aquarium in each group (5 students) (Fig. 4) the explanation about the mechanisms of how water striders can float on the water film has been performed with the teaching materials of photos (Fig. 2, 3, 5) and illustration (Fig. 6).

Explanation 1: Structure of legs

"Numerous hairs are on the surface of legs and oil droplet can be seen among the hairs."

Explanation 2: Surface tension

"Water striders can float with the physic characteristic so called 'Surface Tension'. Have you heard the word, "surface tension?". Because of no responses, the explanation of surface tension was done with the example of a cup filled with water which is still making "hill" beyond the top level of the cup. "The reason why the water does not drop out of the cup is the binding power among the molecules of water. This power is called surface tension."

"Jagged surface of legs due to numerous hairs and oil droplets among the hairs make the surface tension effective for floating of water strider." "Please observe that the legs of water strider floating yield to press on the water film. This is the situation of that the pressure due to the weight of the bug and reaction pressure due to the

surface tension are evenly balanced."

2) Experiment "What does go on floating water striders when a droplet of detergents is put onto the water film?"

In each group, an experiment was performed as follows.

A) A droplet of detergent which had been bought from a super market was put with a pipette onto the water film where water striders were floating and striding in a round-shaped and transparent aquarium (Fig. 1, 4).

B) After the observation of what goes on them, the water striders which had been sunk in the water were rescued onto the dried paper to be recovered.

C) Cleaning behavior with legs on the dry paper was observed.

D) After 5 minutes on the paper, the water striders were back onto the water film to certify that they completely recover in order.

E) Explanation on the mechanism by which the water striders have been sunk was done. "Because the detergent is the surface-active agent, it tries to bind water molecules and oil molecules. These activities reduce the binding power between water molecules and finally the water come among the numerous hairs and the legs sink into the water body. "

3) Explanation on the pollution problems: Water striders and water pollution by detergents used by citizens

"The rivers and water ways where the pollution of waters goes on by detergents used by citizens and increased number of water striders cannot inhabit there. Please think about water striders on water film when you use the washing agents in your home every day."

Results

Comparative analyses were performed between the data before and after the lesson as an intervention lecture. To the question "How do you think water striders can float on water bodies?", the number of students who answered "by using oils excreted from legs" or "surface tension" significantly increased both in elementary school and junior high school groups (Fig. 7) (Table 3A).

The number of students who answered "they sink into water" to the question, "What happens to water striders when a drop of detergent is put in the water?" significantly increased in both elementary and junior high school students (Fig. 8) (Table 3B). As the reasons for water striders to sink into the water after the application of detergent drops, the number of both elementary and junior high students who answered "because water comes between leg hairs" significantly increased after the intervention lecture (Fig. 9) (Table 3B-1). The number of students who answered "because of reduced surface-tension" significantly increased only in the junior high school group (Fig. 9) (Table 3B-1). The number of students who answered "I understand what the word 'surface tension' means" increased after the lecture both in elementary school and junior high school groups (Fig. 10) (Table 3C).

To the question "What kind of organisms are living in the river or its shore?", elementary school students answered 2.94 kinds of animals on average ($\pm$ 2.01 SD, n = 91) (females: 2.94 $\pm$ 2.09, n = 50; males: 2.88 $\pm$ 1.93, n = 41) before the class, whereas the number decreased to 2.34 kinds of animals on average ($\pm$ 1.73, n = 89) (females: 2.57 $\pm$ 1.99, n = 49; males: 2.05 $\pm$ 1.30, n = 40) after the class (Wilcoxon test: .z =-4.26, $p < 0.001$; females:z =-2.97, p = 0.003; males: z =-3.117, p = 0. 001).

Redundant questionnaire might reduce the passion to answer it after the class for young students. On the other hand, 40.3% of junior high school students answered "water striders", to the same question, whereas the percentage was increased to only 62.7% even after the lesson on "water striders" (χ^2-test: χ^2-value = 6.722, df = 1, p = 0. 01). The impact on the psychological impression due to only one lesson seems to be not strong but moderate for the students.

Discussion

This study shows that a lesson including a practical experiment may be an efficient method for teaching elementary school and junior high school students how water striders float on the water surface. However, the term 'surface tension' appears to be difficult for elementary and junior high students to understand. The

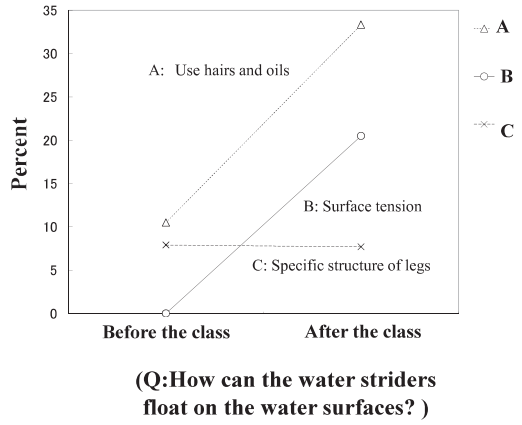

Fig.7. Effects of an intervention lesson on how water striders can float on water surfaces given to elementary school students aged 11-12 yrs. (χ^2-test between "before" and "after": A, χ^2-value = 5.103, df = 1, p = 0.024; B, χ^2-value = 12.062, df = 1, p = 0.001; C, χ^2-value = 0.000, df = 1, p = 1.000)

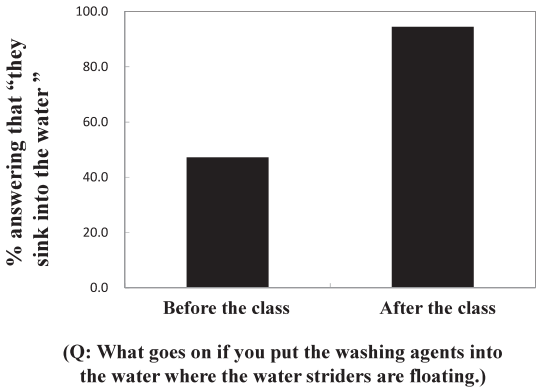

Fig. 8. Effects of intervention lesson on the answer to the question, "What happens if you put a drop of detergent into water in which water striders are floating?" given to elementary school students aged 11-12 yrs. (χ^2-test between "before" and "after": χ^2-value = 195, df = 1, p < 0.001).

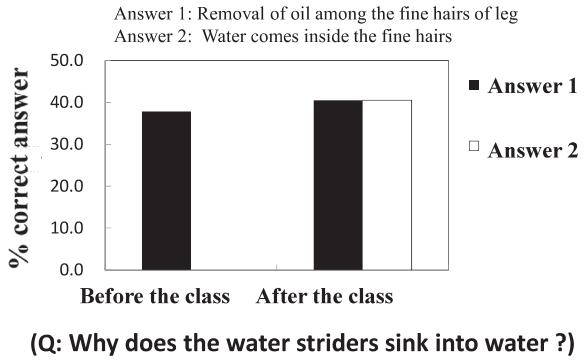

Fig.9. Effect of intervention lesson on % correct answer to the question, "Why does the water strider sink into water when a drop of detergent is applied to the water surface?" given to elementary school students aged 11-12 yrs. (χ^2-test between "before" and "after": Answer 1, χ^2-value = 0.057, df = 1, p = 0.812; Answer 2, χ^2-value = 18.814, df = 1, p < 0.001).

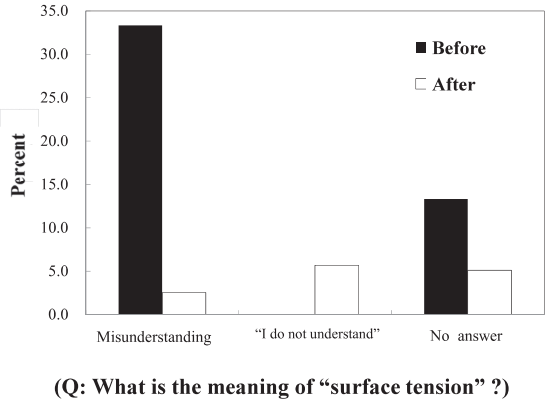

Fig. 10. Reduction of students who answered inappropriately after the intervention lesson given to elementary school students aged 11-12 yrs. (χ^2-test between "before" and "after": χ^2-value = 9.315, df = 1, p = 0.002).

oil that exists within the numerous hairs on the water strider legs may be easily imagined as key factors for floating on water surfaces. In this lesson, time constraints prevented us from teaching the remaining two factors that enable water striders to float on water (Answer No. 1 among three; extremely light body weight of 15-10mg for males and 35-40mg for females and morphological characteristics of legs as large attachment surfaces due to long tarsal and tibia segments of mid and hind legs).

This experiment given in class appears to be effective to some extent for both elementary and junior high school students to teach them that numerous hairs and oil inside the fine hairs on legs are critical for maintaining surface tension of water around legs. It is also effective for teaching students how an organism floats on water.

This subject can be linked to the promotion of efficient teaching materials for 'Education on Environmental

Table 3. Effects of the intervention lecture on answer to questions in the junior high school students aged 13-14 yrs (138 students in total).

A "How do you think water striders can float on water bodies?"							
	Before		After		χ^2-test		
Answer	N	%	N	%	df	χ^2-value	*p*
"Using oils excreted at legs"	23	16.7	53	38.4	1	16.342	<0.001
"Due to numerous hairs on legs"	28	20.3	24	17.4	1	0.379	0.538
"Oils excreted and hairs on legs"	1	0.7	30	21.7	1	30.562	<0.001
"low weight"	15	10.9	8	5.8	1	2.324	0.127
"surface tension"	5	3.6	15	10.9	1	5.319	0.020
B "What goes on for water striders when a drop of washing agent liquid is put on the water body?"							
	Before		After		χ^2-test		
Answer	N	%	N	%	df	χ^2-value	*p*
"water strider sink"	96	69.6	12.5	90.6	1	19.096	<0.001
B-1 "Why does the result you answered to question B occur?"							
	Before		After		χ^2-test		
Answer	N/96	%	N/125	%	df	χ^2-value	*p*
"dissolution of oils"	22	22.9	41	32.8	1	2.602	0.107
"water comes amongleg hairs"	2	2.1	62	49.6	1	59.592	<0.001
"reduced surface-tension"	0	0	6	4.8	1	6.962	0.008
C "Do you understand the word 'surface tension'?"							
	Before		After		χ^2-test		
Answer	N	%	N	%	df	χ^2-value	*p*
"Yes"	26	18.8	68	49.2	1	28.458	<0.001

Conservation Science' in relation to the pollution of rivers due to detergents disposed of by regular people. For example, in the session of "Conservation of natural environment and useful science technology" in the third grade of junior high school (The Teaching Guideline of Science Education, Ministry of Education, Culture, Sports, Science and Technology-JAPAN, 2010b), the following information could be introduced as an appropriate teaching material to introduce a method of environmental conservation. "Water striders and other aquatic insects could be used as a biological indicator of pollution by detergents (Water strider, *Aquarius paludum*: Heteroptera), metals (Brix *et al*. 2011: 38 species from Trichoptera, Ephemeroptera, Diptera, Hemiptera, Odonata, Plecoptera), and physical and chemical conditions which consist of conductivity, hardiness $CaCo_3$, calcium, magnesium, alkalinity, chloride, sulphate, nitrate, phosphate, dissolve oxygen, and B.O.D (Imoobe & Ohiozebau 2009: 24 species from Ephemeroptera, Odonata, Coleoptera, Diptera, Plecoptera, Tricoptera)".

Significance of this teaching material on Teaching Guideline of Science Education for Compulsory Schools (Elementary and Junior High School, made by Ministry of Education, Culture, Sports, Science and Technology-Japan)

According to The Teaching Guideline of Science Education (Ministry of Education, Culture, Sports, Science and Technology-JAPAN, 2010a,b), the teaching material, "How can water striders float and stride on the water surface?" is interdisciplinary material which is appropriate for the following contents in the textbooks.

1. Observation of familiar nature (organisms and their environment which are familiar to our life) (The third grade of elementary school)
2. Organisms and their environment (Relationship between organisms and water) (The sixth grade of elementary school)
3. Animal world (World of invertebrates) (The second grade of junior high school)
4. Organisms and their environment (Examination of natural environment and conservation of environment) (The third grade of junior high school)
5. Characteristics of air and water (The fourth grade of the elementary school)
6. How do substances solve water? (The fifth grade of the elementary school)
7. Power and pressure (The first grade of junior high school)
8. Water solution (The first grade of junior high school)
9. Conservation of natural environment and useful science technology (The third grade of junior high school)

In the textbook, contents of No1 to No4 are included in the biological field. Contents of No 6 and No 8 are in the chemical field, while No 5, No 7 are physics field. The integrated field issue which can be included in the earth science field, is No 9 in the junior high school science education. Therefore, the material, "How can water striders float and stride on the water surface?" in this study seems to be a good model for the teaching materials to be effective for integrative understanding of biological, chemical, physics, environmental conservation and earth science.

Acknowledgement

Thanks are due to all the participants for their kind participation in this intervention study. Thanks are also due to Dr. Hitomi TAKEUCHI for technical supports on making figures and tables and to Ms. Laura SATO (A professional English editor) for linguistic support throughout the text.

References

Andersen, N.M. and Chen, L. 2004. The marine insect *Halobates* (Heteroptera:Gerridae):Biology, adaptations distribution, and phylogeny. Oceanography and Marine Biology: An Annual Review, 42: 119-180.

Brix, K.V., DeForest, D.K. and Adams, W.J. 2011. The sensitivity of aquatic insects to divalent metals: A comparative analysis of laboratory and field data. Science of the Total Environment, 409: 4187-4197.

Bush, J.W.M. and Hu, D.L. 2006. Walking on water: Biolocomotion at the interface. Annual Review of Fluid Mechanics, 38: 339-369.

Cheng, L. 1985. Biology of *Halobates.* (Heteroptera: Gerridae).Annual Review of Entomology, 30: 111-135.

Bush, J.W.M. and Hu, D.L. 2010. Walking on water. Physics Today, 63: 62-63.

Dadour, I.R., Cook, D.F., Fissioli, J.N. and Bailey, W.J. 2001. Forensic entomology: application, education and research in Western Australia. Forensic Science International, 120: 48-52.

Dickinson, M. 2004. Animal locomotion: How to walk on water. Nature, 424: 621-622.

Gao, X. and Jiang, L. 2004. Biophysics: Water-repellent legs of water striders. Nature, 4: 32-36.

Hirose, S. 2005. Creation of a school biotope via participation of children and citizens. Journal of the Japanese Society of Irrigation, Drainage and Reclamation Engineering, 73: 899-904. (In Japanese)

Hu, D. L., Chen, B. and Bush, J. W. M. 2003. The hydrodynamics of water strider locomotion. Nature, 424: 663-666.

Hu, D.L. and Bush, J.W.M. 2010. The hydrodynamics of water-walking arthropods. Journal of Fluid Dynamics, 644: 5-33.

Imoobe, T.O.T. and Ohiozebau, E. 2009. Pollution status of a tropical forest river using aquatic insects as indicators. African Journal of Ecology, 48: 232-238.

Inui, M. Wondering of water striders. Tombow-shuppan, p. 31, 2000. (In Japanese)

Ito, K., Masuda, K., Haruzono, N., Tsuda S., Manabe, T., Fujiwara, K., Benson, J. & Roe, M. 2003. Study on the biotope planning for children's play and environmental education at a primary school-The workshop with process planning methods -. Journal of Japanese Society for Civil Technology (Research Articles on Environmental System), 31: 431-438. (In Japanese)

Ji, X-Y, Wank, J-W, and Feng, X-Q. 2012. Role of flexibility in the water repellency of water strider legs: Theory and experiment. Physical Review, E 85: 021607.

Matthews, R.W, Flage, L.R. and Matthews, J.R. 1997. Insects as teaching tools in primary and secondary education. Annual Review of Entomology, 42: 269-289.

Ministry of Education, Culture, Sports, Science and Technology-JAPAN. 2010a. Explanation of Teaching Guideline for Elementary School Teachers-Science Education, Dainippon-Tosho, pp. 14-17, ISBN978-4-477-01949-9. (In Japanese)

Ministry of Education, Culture, Sports, Science and Technology-JAPAN. 2010b. Explanation of Teaching Guideline for Junior High School Teachers-Science Education, Dainippon-Tosho, pp. 12-15, ISBN978-4-477-01979-6. (In Japanese)

Ranganath, H.A.and Tanuja, M.T. 1999. Teaching and learning genetics with *Drosophila* 2. Mutant phenotypes of *Drosophila melanogaster*. Resonance, 4: 95-104.

Song, Y. S. and Sitti, M. 2007. STRIDE: A highly maneuverable and non-tethered water strider robot. Proceedings-IEEE International Conference on Robotics and Automation. Article Number: 4209216, 980-984.

Song, Y.S., Suhr, S.H. and Sitti, M. 2006. Modeling of the supporting legs for designing biomimetic waterstrider robots. Proceedings-IEEE International Conference on Robotics and Automation. Article Number: 1642046, 2303-2310.

Stork, N. E., McBroom, J., Gely, C. and Hamilton, A. J. 2015. New approaches narrow global species estimates for beetles, insects, and terrestrial arthropods. Proceedings of the National Academy of Sciences 112: 7519-7523. doi:10.1073/pnas.1502408112

Takenaka, S., Kojima, F., Iwata, Y., Yamanaka, K., Nakajo, M., Ishimoto, H., Takahashi, Y. and Harada, T. 2009. Epidemiological assessment on the effectiveness of new teaching materials on the teaching theme entitled “Adaptation of water striders to the life on the water surface and global warming”. Research Reports of the Shikoku-Branch of Society of Japan Science Teaching 27: 27-28. (In Japanese)

Zelkowitz, R 2008. Water striders put best foot forward. Science NOW [http: //news. sciencemag. org/sciencenow/2008/08/08-02.html]-strider.html).