Research Paper

Progress toward the Construction of an International Web-based Educational System Featuring an Improved "SimRiver" for the Understanding of River Environments

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The United Nations has designated water sanitation and safety as one of millennium goals and has emphasized the role of international cooperative efforts in achieving this goal. Promoting awareness to the nations about riverine environments is one approach to this goal and science education has the potential to actualize it. "SimRiver," a program simulator that uses diatoms to enhance the understanding of the relationship between human activity and water quality, is a useful tool for achieving this aim. While previous studies have indicated the advantages of using SimRiver in classroom activities, these studies also revealed the necessity for bringing about improvements in several areas. Revisions were made in both the software itself and in the lesson plans incorporating the use of software, and the effectiveness of these revisions was assessed via a questionnaire study. The results suggest that classroom activities incorporating both the improved version of SimRiver and the enhanced lesson plans succeed in promoting the awareness of river environments more effectively than the previous ones, and in motivating students to conduct additional independent study. In addition, a multilingual version of SimRiver has currently been developed for international use based on the original Japanese version. Web-based multilingual educational teaching aides composed of a Web-based SimRiver simulator, streaming movies, visual tools and a reporting system for classes using these tools are also being prepared in order to encourage international communication in the spirit of the United Nations' millennium development goal.

Keywords: *diatoms, river environment, SimRiver, video movie, web-based system*

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Introduction

The United Nations has designated water sanitation and safety as one of its millennium development goals and has emphasized the role of international cooperative efforts in achieving this goal (United Nations, Web-based resource). The proportion of the population that is able to continuously access purified water is one of the indices for evaluating progress toward this goal. The introduction of both water purification and sewage systems can effectively increase this index. However, promoting national awareness of aquatic environments is also a necessary step in accomplishing this United Nations' goal. Science education has the potential to help accomplish this objective.

"SimRiver" is a useful software application that can provide an enhanced understanding of the relationship between human activity and water quality (Katoh *et al*., 2004; Mayama, 2006). However, previous trials of the software in classroom settings demonstrated the need for improving some of its components as well as the lesson plans associated with its implementation (Mayama *et al*., 2008).

In this study, we address these issues and further present a multilingual Web-based educational system for promoting the development of a collaborative international network focused on aquatic environmental education.

River Pollution

The relationship between river systems and human activity varies both regionally and nationally. Today, in Asian countries with high population densities, sanitary conditions of river systems are often diminished due to an inflow of domestic sewage. In North American and European countries, however, water quality is often diminished through an inflow of fertilizer from agricultural activities.

Over time, water quality in these regions has both worsened and improved based on human interactions. The Japanese economy developed rapidly from the mid-1950s to mid-1970s, resulting in the severe pollution of many of the nation's rivers (Fig. 1). Following this development period, the amount of dumped garbage decreased, but the water quality still suffered due to a direct inflow of domestic sewage that continued until the 1980s. Similar aquatic conditions occurred in North American and European countries during this period. In the late 1960s, environmental pollution was a growing concern in the United States and Canada. In the early 1970s, Lake Erie, a part of the St. Lawrence River, was declared "dead" due to extreme levels of chemicals and other pollutants (Environment Canada, Web-based resource). In Europe during the late 1970s, the Main River was in a grave condition due to heavy sewage from German industrial plants (Lange-Bertalot, 1978, 1979). In Korea, which has seen an economic boom since the middle of the 1960s, the Han River became heavily polluted until the end of the 1980s due to the city's dense population and industrial activities in its catchment area (Environmental Information Network in North East Asian Region, Web-based resource).

While these countries have attempted to overcome their serious water problems by enacting protective legislation, expanding their sewage systems, and developing treatment technologies, these efforts have not fully resolved their water contamination issues. Japan, for example, has achieved substantial improvement in its urban areas, e.g., in Tokyo sewer coverage is at 99%, but in 13 of its 47 prefectures, coverage remains under 50% because of mountainous landscapes (Ministry of

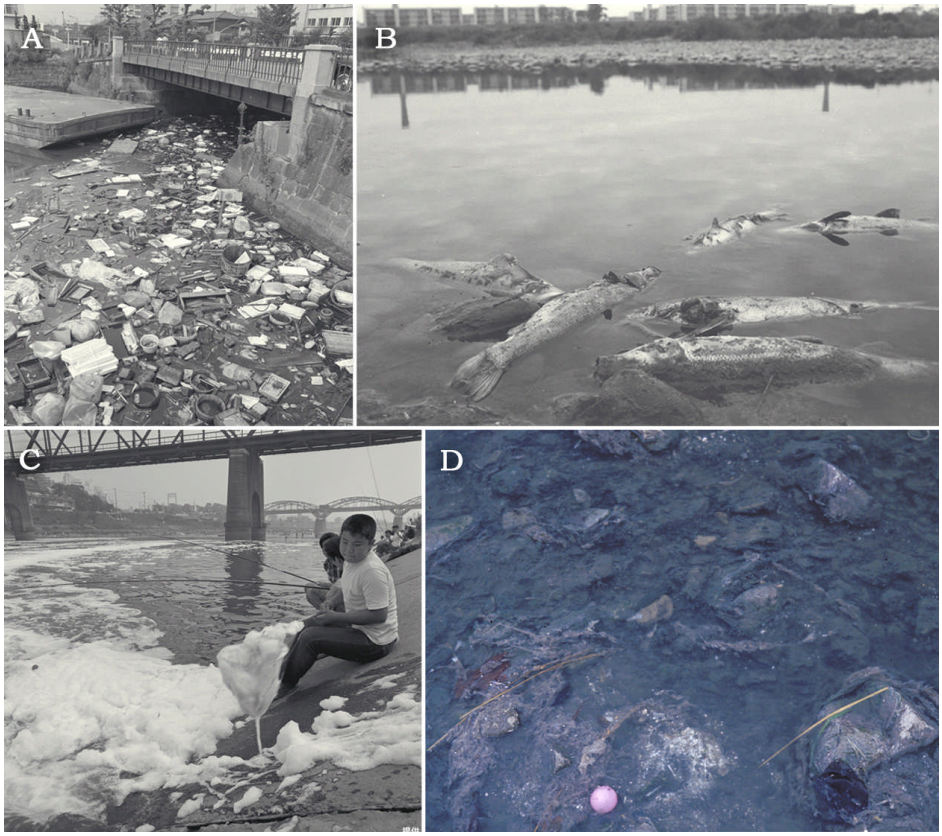

Figure 1 Polluted rivers in Tokyo, 1960-1970's. A. Much strewn garbage. B. Dead fish caused by O_2 deficiency. C. Huge amount of foam caused by domestic detergent. D. Gunmetal-grey water and riverbed covered with slime. A-C. ©Tokyo Metropolitan Government Bureau of Environment.

Land, Infrastructure, Transport and Tourism, Web-based resource). Moreover, outside these nations, there are regions around the world where water protection and sanitation have barely improved. This situation is particularly prevalent in parts of Asia, South America and Africa.

Difficulty in Using Science Education to Solve Environmental Problems

Because alterations in river environments usually take place over an extended period of time, it can be difficult for students to understand the actual process of environmental change within short-term classroom settings. Therefore, students tend to accept information regarding environmental degradation of rivers as mere knowledge, with a lack of meaningful context. As experience-based exercises are often most effective in science learning, we developed SimRiver, a software simulation package. In the program, land use, population, the presence of sewage treatment plants, and the seasons can be manipulated, allowing students to create a variety of river environments. Students can evaluate the impact of environmental manipulation through the use of computer-generated diatom communities reflecting the water quality in electronic river systems (Katoh *et al*., 2004; Mayama, 2006) (Fig. 2). Students utilizing the SimRiver package can therefore better understand the relationships between human activity, river water quality, and diatom communities.

Although the term "diatom" is found in every science textbook in Japanese junior high

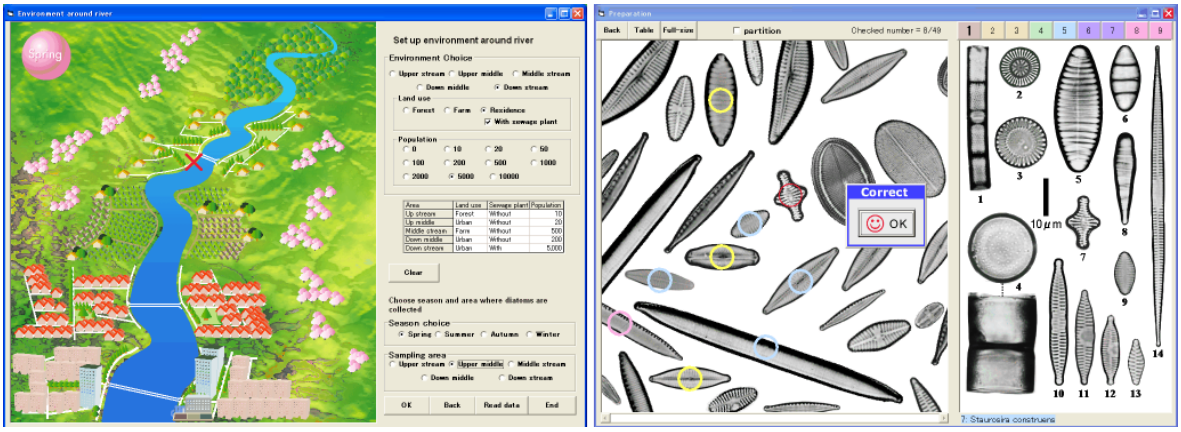

Figure 2 SimRiver ver. 3, English version. Set up window for environment along a river (left). A view of a computer-synthesized diatom slide equipped with a built-in identification support system (right).

schools (Katayama, 2010), the word is often inset with only a small photograph or drawing identifying them as aquatic microorganisms, with no further explanation. Consequently, despite their great potential for science education, diatoms are organisms that are not well known by students or teachers (Mayama, 2005). To promote the awareness of diatoms and their utility in science education, we developed additional educational tools that can support lessons utilizing the SimRiver program. These additional resources include a three-part streaming video series (see Mayama *et al.*, 1996, for the original scenario) and a Flash video collection of diatoms, "Visual knowledge" and "Encyclopedia." These resources are available at the following site (Fig. 3):

http://lbm.ab.a.u-tokyo.ac.jp/%7Ekeiso/diatom4/

SimRiver

Brief Review of the Software Development

The release of SimRiver dates back to the beginning of this decade. The archetype of SimRiver was not a simulator but simple HTML Web pages supporting diatom identifications. These Web pages were composed of a dry lab utilizing diatoms, which came from

Figure 3 The top page of the comprehensive website "Let's learn about river environments from microorganisms, Diatoms" available in Japanese.

the paper-based version of the lab (Ueyama and Kobayasi, 1986). Junior high and high school students carried out the exercise using the dry lab favorably in an extracurricular setting (Mayama, 2001). The development of the simulator version, SimRiver ver. 1, began in 2002, when a program for water quality estimation and a display program for the diatom community were combined.

Once together, the reliability of the computer-generated data was tested. Moreover, since they had been used for 17 years by some local governments (e.g., Tokyo Metropolitan Government Bureau of Environment, 2003), three categories of diatom pollution tolerance (Kobayasi *et al.*, 1985; Kobayasi and Mayama, 1989; Mayama, 1999) were employed as parameters for a saprobic index within the simulator. These categories were as follows: Group A, the most tolerant diatoms; Group B, moderately tolerant diatoms; and Group C, sensitive diatoms (for further details, see Kobayasi and Mayama, 1989).

SimRiver ver. 2 was created based on the results of various tests of ver. 1 (Katoh *et al*., 2004). The use of this tool was welcomed by many students and motivated some of these students to learn more about river environments and seemed to increase their understanding of water resource issues (Mayama *et al*., 2008). However, a detailed TWINSPAN analysis of the students' own written descriptions of the subject indicated that nearly 40% of them did not hold an interest in water resource issues, but were merely interested in manipulating the simulator and testing overall performance (Mayama *et al*., 2008).

Software and Lesson Plan Improvement

In this study, we improved not only SimRiver ver. 2, but also the lesson plan designed for classes using the software (Table 1).

The previous lesson plan focused on letting students understand the relationships between human activities, water quality, and diatom communities, by only using a saprobic index. However, as this index was difficult for students with poor math skills to calculate, the use of this index resulted in the potential loss of students' interest. In the revised lesson plan, we intended to focus the students' attention on species richness as well as the ratio of species, which were classified into three categories of diatom pollution tolerance. In biology education, learning the relationship between a species and its environment is critical in understanding the concept of bioindicators. To support students understanding of the principle of bioindicators, the improved version, SimRiver ver. 3, generates a graph in each simulation, demonstrating the ratio of species in three pollution tolerance categories. In the same window, a map of a river reflecting the environmental parameters that have been modified by the user on the initial setup screen, is displayed (Fig. 4).

Additionally, the operation of the built-in identification support system was changed to simplify its use and save time, i.e., all operations requiring a right-click were omitted. In the revised lesson plans, we also included time for watching the part 1 of the video "Diatom."

Assessment of SimRiver ver. 3 through a Class Survey

To assess the operability of SimRiver ver. 3 and to understand students' interest in the activities, a questionnaire survey was conducted in the classes to which the revised lesson plan including the use of above-mentioned educational tools had been applied. The classes surveyed included junior high school A (public, coeducation), junior high school B (private girl's school), high schools A and C (public, coeducation, almost all students intend to go on to university), high school B (public,

Table 1 Improved lesson plan. The basic plan is shown below, the details of which were slightly changed when implemented in classes depending on the student levels.

Time	Activity
0 (min)	Introduction * Teacher shows a bottle of mineral water to the students and asks "Has anyone tasted water like this?"** Students: "yes." * Teacher: "Why did you drink it?" Students: "Tap water doesn't taste good." * Teacher: "Do you know why tap water doesn't taste good?" Students: "No I don't." * Teacher: "Chemicals are added to tap water at water purification plants. Why are chemicals added?" Students: "The water is polluted." * Teacher: "Heavily polluted water is not used for tap water, but the addition of chemicals is necessary for making sure it is safe to drink." Teacher: "Do you know how people can know the level of water pollution?" Students: "Maybe we can use a chemical or electric sensor." Teacher: "Yes. But there is another method, in which people employ organisms as a bioindicator to assess a river environment. In this lesson I will introduce diatoms as an example of a bioindicator."
8	Video * Watch part 1 of the video "Diatoms"***
13	Teacher answers students' questions
16	Teacher questions the students
18	Explanation of the activity using SimRiver. * Level 1 is used for easy understanding of the software operation.
35	Student group activity * In each group, composed of 5 students, the members discuss what environments they will create along two different rivers in the software and decide who will handle which area.
45	Student personal activity using SimRiver at level 3 Each member sets up his or her environment, which is shared with the other members of the same group, and then works on an assigned area. * After obtaining their results, the data will be exchanged among the members in order to give them an understanding of the changes of species richness, the ratio between species classified into the three categories of diatom pollution tolerances, and a saprobic index corresponding to the river environment from upstream to downstream.
100	Discussion
110	End

* Newly added activity in the improved lesson plan.

**Japanese were not accustomed to drinking bottled water on a regular basis until about 25 years ago. In the past 20 years, the consumption of bottled water has increased.

*** We produced parts 1 to 3 of the video. The contents of part 1 are an easy introduction of diatoms and a method of diatom collection in a river system.

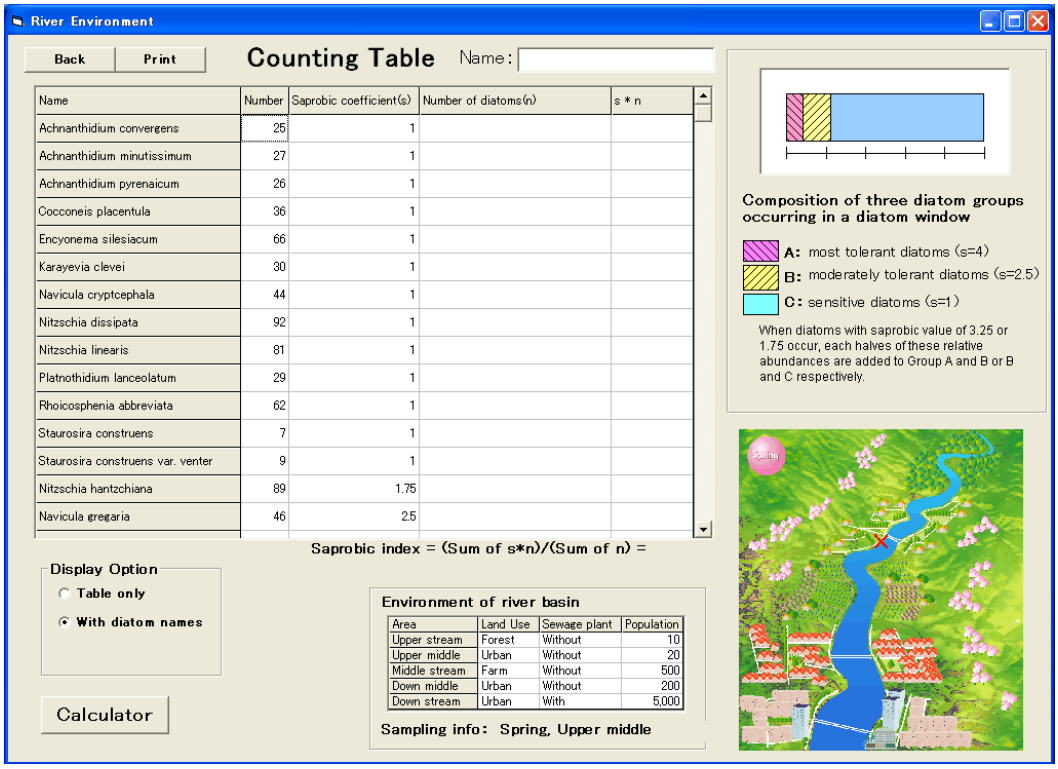

Figure 4 SimRiver ver. 3, English version. Window of counting table with a newly added environment map and a graph which shows the ratio of the counted diatoms classified into three categories.

coeducation, almost all students intend to go on to vocational college), and extramural classes A, B, and C (composed of junior high and high school students who attended the classes voluntarily). The survey questions used for these evaluations were identical to those used in a previous study (Mayama *et al.*, 2008). For each question, students were asked to choose one number from a one-to-five attitude scale, corresponding with their opinion. Although the learners were different between the present and previous classes, the results indicated a significant shift in the students' response, suggesting a substantially successful improvement (Figs. 5, 6). In fact, poor scores (one to three on a five scale) were recorded less frequently in the present survey compared to the previous one despite an increment of the total number of students. Differences in scoring patterns for high school B and junior high school B, when compared to other classes, may be related to the specific profiles of these schools and students above mentioned in parentheses.

The questionnaire survey also showed a qualitative difference in the written descriptions between previously surveyed classes (Mayama *et al*., 2008) and classes that had applied the revised lesson plans developed in this study. Examples of typical descriptions in the previously surveyed classes include the following:

- "Creating an environment on my own was a good experience."
- "The game-like learning was easy and fun."
- "I felt the lesson period to be shorter than usually."
- "If such classes increase, I will have more fun in school."

Remarkably, descriptions reflecting a

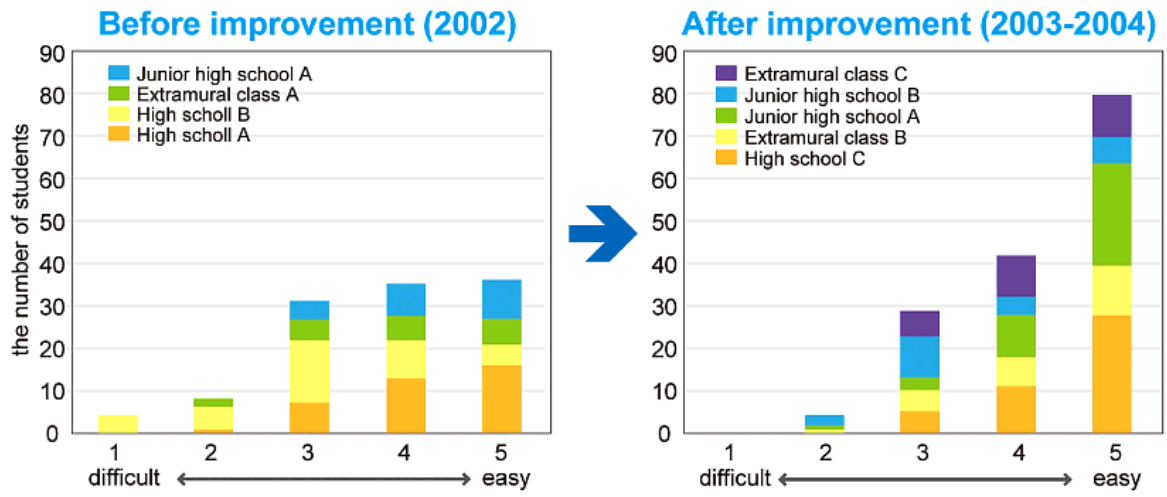

Figure 5 Comparison of operability between the ver. 2 and ver. 3 of SimRiver software assessed by students. N=114 (2002) and N=156 (2003-2004). Left graph: after Mayama *et al.* (2008).

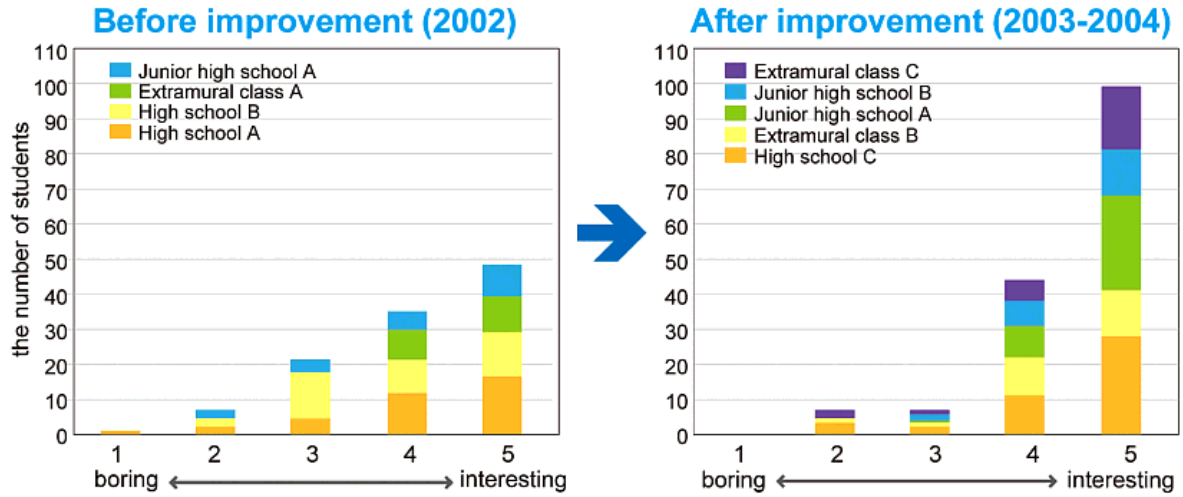

Figure 6 Comparison of students' interest in the lesson between the classes using the former lesson plan with SimRiver ver. 2 and those using the revised lesson plan with SimRiver ver. 3 and the video movie. N=114 (2002) and N=156 (2003-2004). Left graph: after Mayama *et al.* (2008).

concern for environmental protection and an attitude toward taking care of the environment in daily life were written by students who had been given a set of the improved program and lesson plan. Such descriptions include the following remarks:

- "If the environment becomes good, water quality will be better and organisms, which cannot live in polluted water, can increase. This means the conservation of the environment is linked to the conservation of organisms."
- "I learned that thinking about the global environment where we live is very important. I think of the importance of attitude to seeking what I can do for making environment better."
- "It is important that each person thinks about something good to do for our environment and does not depend solely on the

self-purification of rivers or on solutions made by limited specialists.

In the previous survey, 43.8% of the respondents did not show any interest in river environments in their written descriptions (Mayama *et al*., 2008), and thus a resolution of this problem was expected in the use of the new program and lesson plan. In the present survey, the descriptions showing an interest only in the use of the computer or software decreased to 7.7–13.6% in 5 different classes (10.8% in total descriptions), and the ratio of descriptions referring to river environments increased to 88.6% (Table 2).

The question for the written descriptions was "What thoughts do you have after this lesson?" and did not try to elicit any specific answers, allowing the students to write a description reflecting their own personal and spontaneous awareness. Therefore, the results indicate that the improvements in the software and lesson plan were effective for the promotion of student awareness of river environments.

In the survey for students at high school C, we added additional questions concerning their understanding of bioindicators and their motivation for further study. The students were again asked to select one number from a one-to-five attitude scale, corresponding with their opinion. This self-assessment indicated a possible effect of the lesson plan incorporating SimRiver on promoting student understanding of bioindicators (Fig. 7) although it should be confirmed by additional quantitative testing. The survey also indicated an increased motivation for further study in many students (Fig. 8).

Table 2 Comparison of student concerns regarding river environments between the previous and present surveys. In the present survey, the improved software and lesson plans were used in the class activities.

Group*	Previous survey** (%)	Present survey					
		Junior high school B (%)	High school C (%)	Extramural class B (%)	Extramural class C (%)	Junior high school A (%)	Total (%)
A	43.8	13.6	12.8	12.5	7.7	7.7	10.8
B1	21.4	36.4	23.4	33.3	34.6	43.6	33.5
B2	12.5	36.4	51.1	45.9	53.9	43.6	46.9
C	21.4	13.6	10.6	8.3	3.8	5.1	8.2
D	0.9	0	2.1	0	0	0	0.6
Sum	100	100	100	100	100	100	100
n	112	22	47	24	26	39	158

* Groups recognized in past written descriptions (Mayama *et al*. 2008).

A: composed of students who described only an interest in the use of either the computer or software.

B1: composed of students who described an interest in the use of either the computer or software, and referred to rivers, the environment, and/or diatoms.

B2: composed of students who described an interest in the self-creation of an environment in the software operation and referred to rivers, the environment, and/or diatoms.

C: composed of students who did not show an interest in the computer and software, but referred to diatoms and the entire lesson.

D: composed of students who showed no interest in the lesson.

** Mayama *et al.* (2008)

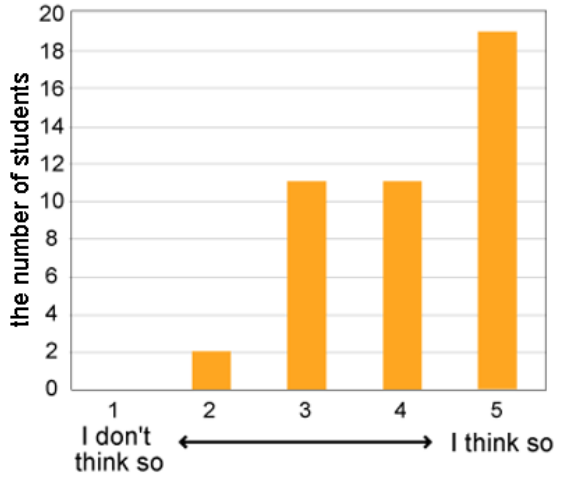

Figure 7 Students' self-assessment on promotion of the understanding of bioindicators. N=43. [Question: Do you think that your understanding of bioindicator was promoted?]

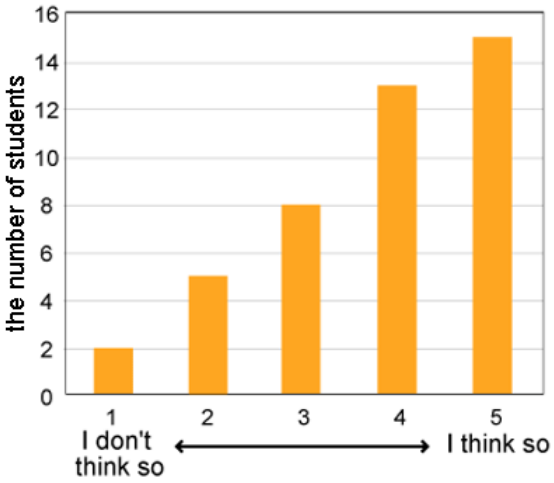

Figure 8 Students' self-assessment on motivation for further studies. N=43. [Question: Do you want to collect and observe diatoms?]

After the implementation of the new lesson plan used in this study, we introduced our project in many other situations, thus exposing more than 1,700 students to the lesson. We have also analyzed the effectiveness of the lesson in these cases and have partially reported on the results of these implementations (Mayama *et al*., 2007, 2009; Nakamura *et al*., 2008). Despite the fact that diatoms were not familiar organisms to the students prior to the implementation of the lesson, these results also indicate a promotion of student awareness on aquatic environments.

Production of Multilingual Educational Tools

SimRiver and its related educational tools were originally produced in Japanese, and it became necessary to prepare versions in other languages for international use. We believe the use of native languages is important in the promotion of a nation's awareness of river environments, as most classes in every country are taught in their native tongue. Therefore, we have begun producing multilingual editions of the SimRiver and its support tools based on the original Japanese version. At present, we have completed video programs on diatoms in English, Korean, Portuguese, Polish, Thai, German, French, Spanish, Russian and Chinese, and the SimRiver software has been packaged in English, Korean, Portuguese, Thai, German, Spanish, Chinese and French. Additionally, Russian and Indonesian versions of the software and an Indonesian version of the video program are currently in production. As students tend to be familiar with only their own present river environments, we also offer multilingual visual tools at a Website to introduce the circumstances of various water environments in different areas and in different time frames in order to enhance student insight on aquatic issues worldwide. Completed products are available on the website "Diatom Project." (Fig. 9):
http://www.u-gakugei.ac.jp/~diatom/

Construction of an International Educational System

To achieve the objective of our project, we are developing an advanced Website system (Fig. 10). In this system, we have

Figure 9 Top page of the website "Diatom Project" from which users can access the multilingual educational tools. (accessed 01/10/2010)

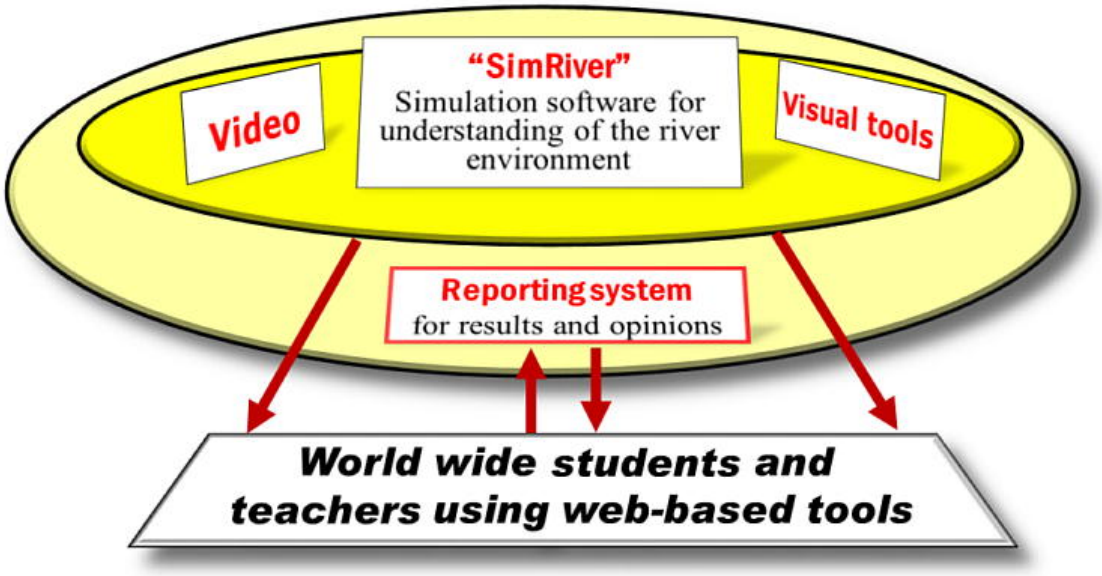

Figure 10 Diagram of a web-based educational system for international understanding through river environment.

produced SimRiver ver. 4 in Japanese, programmed using Java Script and HTML, which can be used directly on a Web browser. SimRiver ver. 3 needs to be downloaded and installed on a computer before use, as it was originally written in Visual Basic. However, school computers often have security protocols limiting software installations, and therefore teachers have to spend a great deal of time preparing the classroom computers before using ver. 3 of the software. The SimRiver ver. 4 is being improved based on the results of

preliminary trials conducted at two junior high schools (unpublished data). After the modifications are complete in the Japanese version, various language versions of SimRiver ver. 4 will gradually be produced; very recently, an English version was released (Hoffer *et al.*, 2011). The downloadable versions will still remain on the Website, "Diatom Project," for schools in the regions where Internet access is inconvenient.

The combination of video program, the SimRiver program itself, and other visual tools creates a unique system that allows students to learn about changes in river environments from the past to the future during a class course.

The use of the same educational tools will be able to promote students' ability to compare thoughts about river water issues from a shared perspective. To facilitate this opportunity, we are preparing a reporting system that will be located on a Website for gathering classroom results based on their use of these tools. The system will be composed of a form for gathering their thoughts and opinions, a table showing their reports, a map indicating the areas where the reporters live, and simple automatic translators. Using this system, students will be able to share and compare their experiences with others around the world. This system will also allow students to communicate easily and internationally, resulting in the promotion of global friendships.

Various results, impressions, and opinions reported on the Website from classes around the world will lead students to discover not only the differences in river environments, but also the different thoughts of people spreading across the globe. This is meaningful for students to understand variations in national circumstances, allowing them to contemplate worldwide cooperation. Thus, the effective execution of this system will be a significant event for sustainable development, and will allow us to invite people from any country to join the project in order to help in accomplishing this goal.

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