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A Lesson Model Fostering Fine Ideas in Chemistry Concerning Biodiesel on the Basis of "Education for Sustainable Development": Potentialities for Collaboration with Social Studies

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Abstract

The purpose of this study is to develop a lesson model fostering students' ideas of chemistry on the basis of “Education for Sustainable Development (ESD)” in collaboration with social studies. The main topic of the lesson proposed is biodiesel. The lesson consists of the following four parts: (1) A lecture about the fundamentals of biomass fuels, (2) Experiments on the biodiesel syntheses and measurements for combustion efficiency of liquid fuels, (3) Student Discussion of biodiesel through team-teaching with specialists in chemistry and social studies, (4) An activity about evaluating of biodiesel. The lesson was conducted with 40 first grade high school students. Pre- and post-evaluation were carried out. The evaluation shows the following: Students discussed biodiesel from the aspect of natural science and also social science, which fostered ideas concerning sustainable development, for instance, the efficiency of fuels, the cost of fuels, the acquisition of raw materials, the influences on environment and preservation of the environment. Moreover, the lesson encouraged students to understand the importance of different viewpoints when they worked on environmental issues.

Introduction

The main topic of the lesson proposed is biodiesel. It is a biomass fuel which attracted great public attention as an alternative fuel because it is carbon neutral. However, students lack in the knowledge about biodiesel and the ability to judge energy problems from social viewpoints. Therefore the purpose of this study is to develop the chemistry lesson model

which includes the lecture by a social studies teacher and team-teaching with chemistry and social studies teachers. And the lesson model was also developed in relation to “Education for Sustainable Development (ESD)”.

Contents of the lesson

1. Lecture about the fundamentals of biomass fuels (1hour)
2. Experiments on the biodiesel syntheses and measurements for combustion efficiency of liquid fuels (2hours)
3. Student Discussion of biodiesel through team-teaching with specialists in chemistry and social studies (1.5hours)
4. Activity about biodiesel evaluation (0.5hour)

Teaching materials for the lecture and work-sheets for the experiments and evaluation for students' activities were modified from the original Berlin model, which was developed by Bolte, C. and Kirschenmann, B.[1][2]. Contents of Japanese school textbooks were incorporated into the materials in order for Japanese students to be able to use it. The work-sheets and evaluation-sheets were exactly the same as these in the Berlin model.

Teaching procedure of the lesson model

The lesson was conducted with 40 first grade in Hiroshima University High School students.

1. Lecture

This lecture was given by a chemistry teacher. The lecture deals with three types of fuels: wood as a solid biomass, biodiesel as a liquid biomass, and methane as a gas biomass. Chemical composition, energy from the combustion and ways of producing wood were introduced. The principles of biodiesel syntheses (Transesterification : $C_3H_5(OCOR)_3 + 3CH_3OH \rightarrow 3CH_3OCOR + C_3H_5(OH)_3$), bio-oils as materials and chemical composition of oils were introduced. Methane fermentation and biogas factories were discussed.

2. Experiments

These two experiments were carried out by the students

1) Biodiesel syntheses

① Put 0.4g NaOH in a 50cm^3 beaker containing 6cm^3 methanol and dissolve NaOH completely by stirring. → solution①

② Add 54cm^3 rapeseed oil to 12cm^3 methanol in a 300cm^3 round-bottom beaker. → solution②

③ After setting up the equipment (Fig. 1), stir solution② with a hot magnetic stirrer, keeping the water temperature water at about 70℃.

④ In 7 minutes, add solution① to the round-bottom beaker and stir, keeping the water

temperature at about 70℃.

⑤ In 10 minutes, stop heating, add 40cm^3 HCl (0.1mol/L) to the round-bottom beaker and stir the solution.

⑥ After letting the solution stand, take off the upper layer. This layer is biodiesel.

2) Measurements for combustion efficiency of liquid fuels

① Add biodiesel (or light oil, kerosene, ethanol, methanol) to a spirit lamp and then measure the weight of the spirit lamp.

② Add 200g water to a 500 cm^3 Erlenmeyer flask and set up the equipment (Fig. 2).

③ Light the spirit lamp and record the temperature every 30 seconds.

④ In 7 minutes, extinguish the sprit lamp and measure its weight.

⑤ Calculate the combustion efficiency of liquid fuels, based on the weight and the change in temperature.

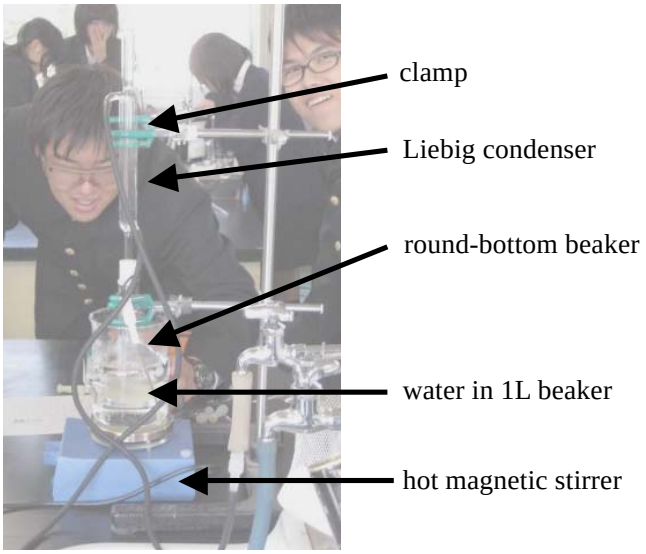

Fig. 1. Syntheses of biodiesel

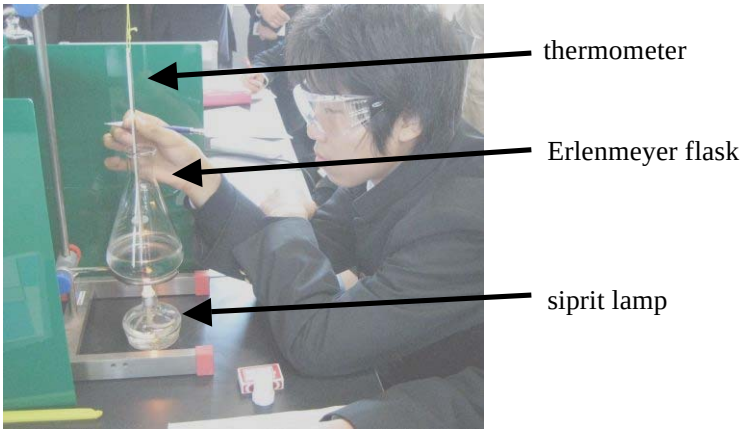

Fig. 2. Measurements of combustion efficiency

The combustion efficiency is presented in Table 1. The combustion efficiency is represented by the rise in temperature of 200g water by means of 1cm^3 fuel. Table 1 shows biodiesel is the best.

Table 1. Combustion efficiency of liquid fuels

Fuels	Combustion Efficiency ［K/ cm^3］
Biodiesel	20
Light oil	15
Kerosene	16
Ethanol	12
Methanol	10

3. Student Discussion

1) A lecture by a social studies teacher

The lecture on biodiesel was given by a social studies teacher (Fig. 3); its economic efficiency, the raw materials, the influences on environment, the relation with fossil fuels and efforts made by each country related to biodiesel[3][4] were discussed.

2) A discussion

Based on the lecture given by the chemistry teacher and the social studies teacher, a discussion by students on the possibilities of biodiesel, the experiments with biodiesel, and comparison of biodiesel, light oil, kerosene etc., was conducted (Fig. 4).

Fig. 3. Lecture by a social studies teacher

4. Activity

Students were divided into ten groups, consisting of four students each. Each group made up five criteria which they thought were important for assessment of biodiesel and light oil. Then using the “Table of Assessment” sheet (Table 2), each of the students determined the importance factor of each criterion by allocating a total of 20 points to the five criteria. The students allocated performance values to each criterion [1 = very good to 5 = inadequate], calculated the total value by multiplying the performance value of each respective criterion with the importance factor to the respective criterion and divided the sum of the total value by 20 in order to calculate the final grade.

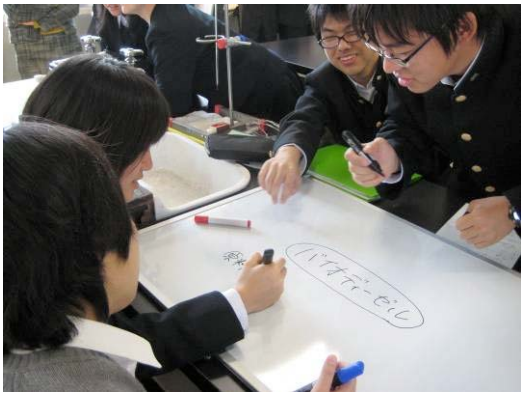

Fig. 4. Discussion about evaluation of biodiesel

Table 2. Table of Assessment

Biodiesel			
Criterion	Importance factor	Performance value	Total value
A			
B			
C			
D			
E			
Sum	20		
			:20
Final Grade			

Discussion: Evaluation of the lesson model

1. Table of Assessment

Table 3 shows the criterion chosen, the number of groups which chose each criterion, and the number of students in the groups who allocated the highest points to a criterion. But when one student allocated the highest points to more than two criteria, the number of students was counted in each criterion category.

Table 3. Criterion for assessment of biodiesel and light oil

Criterion	the number of groups	the number of students	
		Biodiesel	Light oil
Combustion efficiency	10	9	12
Cost	10	15	18
Influences on environment	8	14	15
Amount of CO_2 emission	2	7	7
Safety	6	5	6
Production efficiency	4	2	2
Easy to use	3	1	0
Easy to get	2	0	0
Acquisition of raw materials	2	0	1
Future	1	2	2
Others	2	0	1

As Table 3 shows, all the ten groups chose "combustion efficiency" and "cost" as important criterion. It is clear that thoughts about "combustion efficiency" are related to the experiment which was carried out by the students and also ideas of "cost" came from the lecture by the social studies teacher.

Table 4 shows the mean scores of the final grade which all the students calculated. Mean scores are significantly different ($p<.005$). So the students judged that biodiesel was the better fuel, based on "Table of Assessment (Table 2)" in which the criteria above were written.

Table 4. Mean scores of the final grade

Biodiesel	2.6
Light oil	3.0

2. Concept forms: (1) An Energy Concept Map, (2) A Biodiesel Concept Map, (3) A Discussion form were given to students before and after the lesson.

1) Energy Concept Map

As Fig. 5 shows, in the post-evaluation, students wrote words related to "environmental protection, carbon dioxide, new energy, food problems", which most of the students did not

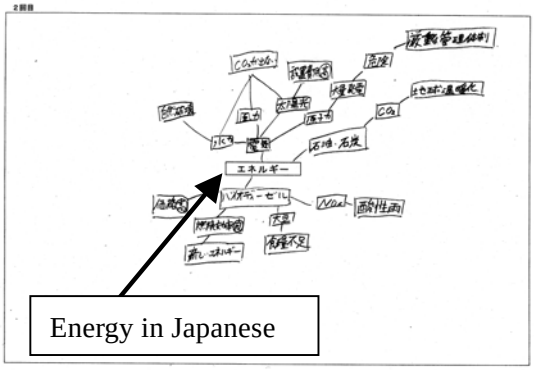

Fig. 5. Energy Concept Map drawn by a student in the post-evaluation

write in the pre-evaluation.

2) Biodiesel Concept Map

As Fig. 6 shows, in the post-evaluation, the number of words linked to biodiesel increased, compared with the pre-evaluation.

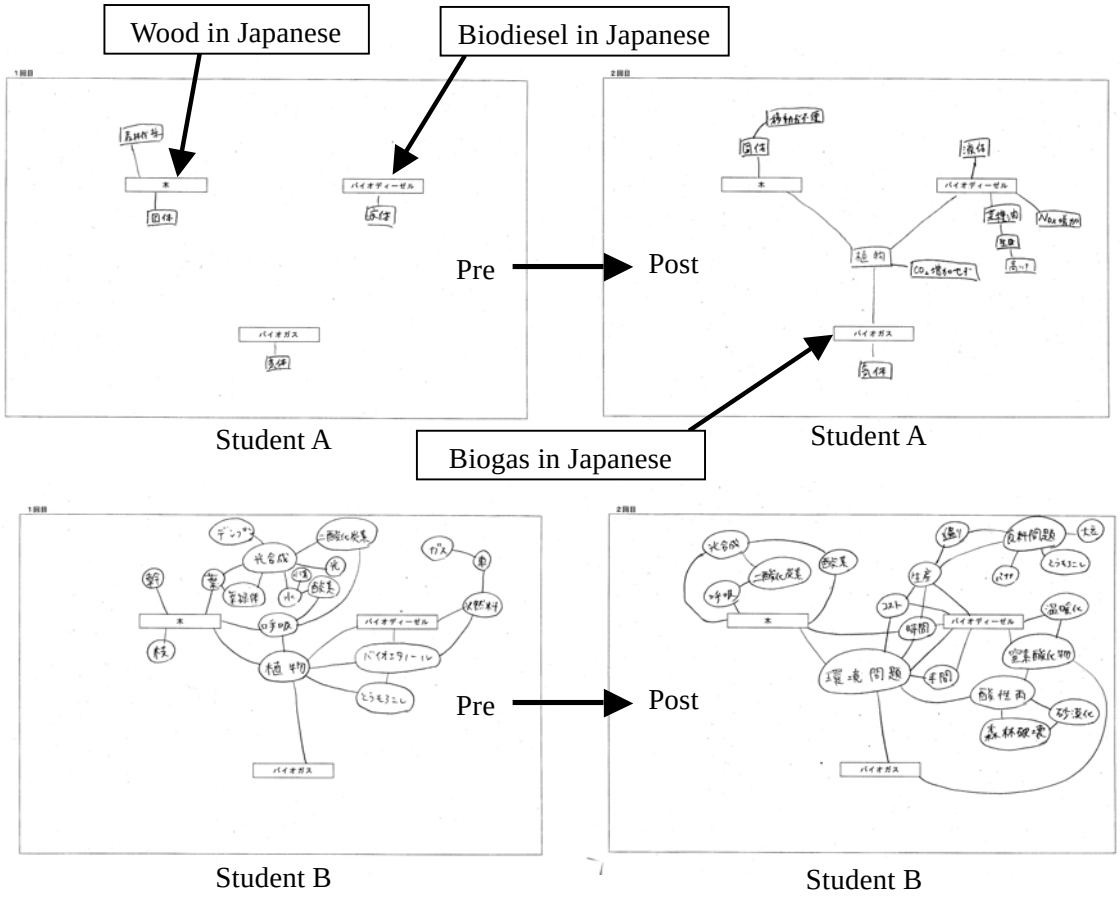

Fig. 6. Concept Maps about biodiesel, wood, biogas drawn by students in the pre- and post-evaluation

In the pre-evaluation, the total number of words linked to biodiesel was only 167 including words which were not related to science. In addition, seven of the 40 students did not write any words. The pre-evaluation revealed that students' concern about biodiesel was low.

In the post-evaluation, the total number of words increased to 276. Furthermore, almost all of them were related to science and there was no student who did not write any words. Words related to raw materials such as "rapeseed oil, a soy bean, palm oil, lack of food" and the environment such as "CO_2 reduction, deforestation, the environmental problems" greatly increased.

3. Reasons for agreement with and opposition to the construction of energy supply facilities.

In the pre-evaluation, more than half the students did not give any reasons for both

agreement with and opposition to the construction of biodiesel and biogas energy supply facilities. The pre-evaluation revealed that students' recognition of bio-energy was insufficient. As Fig. 7 and 8 show, in the post-evaluation, the number of reasons the students gave for both agreement with and opposition to biodiesel increased greatly. Moreover, the number of reasons given for agreement and opposition was the largest with biodiesel.

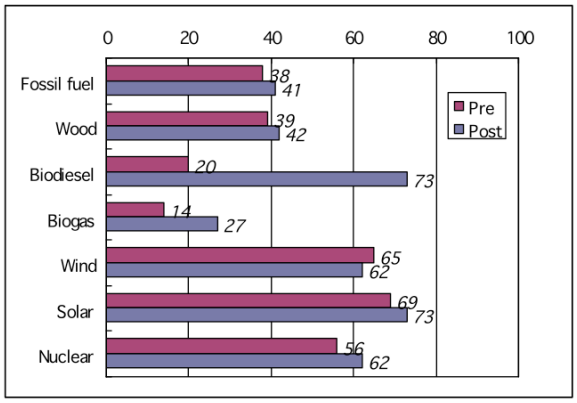

Fig. 7. Number of reasons for agreement

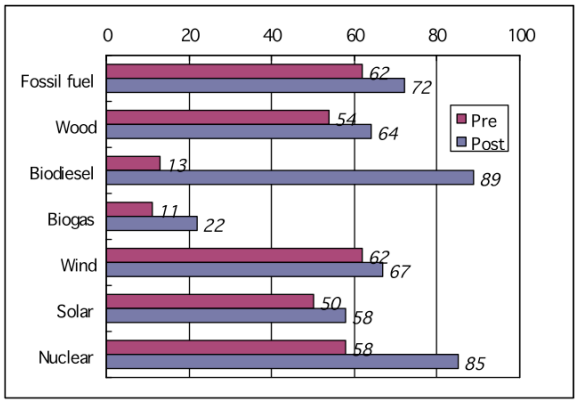

Fig. 8. Number of reasons for opposition

As the reasons for agreement with biodiesel students wrote "less CO_2 emission, eco-friendly, better combustion efficiency and future use", and as the reasons for opposition to biodiesel "the cause of lack of food, the use of fossil fuels in a process of production, difficulty of mass production, long time to produce, and its cost".

As Fig. 8 shows, there was also a large increase in the number of reasons for opposition to nuclear power. That might be because the fact that Germany, which is thought to be an environmentally advanced nation, has stopped nuclear generation was introduced in the lecture by the social studies teacher.

As mentioned above, the number of words concerning natural science (chemistry) and also social science increased in the post-evaluation of concept map. It is clear that the collaboration between chemistry and social studies had an effect on the students. And the number of reasons for both agreement with and opposition to biodiesel, which is the main topic of this lesson, increased in the post-evaluation.

Conclusion

These results show the following. The consideration of biodiesel from the aspects of natural science (chemistry) and also social science fostered student’s ideas concerning perspectives of sustainable development, for instance, combustion efficiency of fuels, economic cost of fuels, possibility of acquisition of raw materials, influences on the environment and maintaining the environment. Moreover, the lesson encouraged the students to understand the importance of different viewpoints when they worked on environmental

issues.

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