Chapter 22
Innovative Lesson Plans in Chemistry Education for Broadening Sustainable Society

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Abstract Expanding Education for Sustainable Development (ESD) is one of the big challenges for education in Japan. Science educators are also tackling the link between science education and ESD, and focusing on promoting students' understanding of key concepts for sustainable development and enhancing their abilities in making appropriate judgments on science, technology, society, and environment (STSE) issues. We developed chemistry lesson models for upper secondary school that reflect the viewpoints of ESD. The lesson topics cover bioenergy like biodiesel, biological resources like chitin and chitosan, and metal resources like iron. After conducting trial lessons for students in both Japan and Korea, we evaluated the lesson with the outlined objective of promoting students' abilities to make appropriate judgments based on their knowledge of science. The results show that the lessons achieved a measure of success, and also provided an excellent opportunity for the students to consider the possibilities for establishing a sustainable global society.

22.1 Introduction

Science educators in Japan have been tackling the challenge of how to make innovative lessons that broaden sustainable society, following the turning point that was the decade of Education for Sustainable Development (ESD) declared by UNESCO (2005–2014). Consequently, research and practices in science lessons have gradually increased. These lessons have focused on the promotion of students' understanding of key concepts related to sustainable development, such as circulation, symbiosis,

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diversity, preservation and respect for life, and also on that of students' abilities to make appropriate judgments on STSE issues. Examples of issues include natural resources, energy, transport, electronics, food, health, cosmetics, medical treatment, and biotechnology. The above-mentioned key concepts must be integrated with these issues.

We have developed chemistry lesson models for upper secondary school that enhance students' abilities to make appropriate judgments on the topic of bioenergy-like biodiesel, biological resources like chitin and chitosan, and metal resources like iron. Through these lessons, the students were expected to be able to: (1) recognize a science-related problem in connection with social and environmental issues; (2) think of possible solutions based on their understanding of content knowledge; and (3) make appropriate judgments directed toward solving a given science-related problem and taking action. Some findings, as shown from the trials and evaluations of the lessons, indicate that they helped promote students' judgment abilities based on their knowledge of science and at the same time facilitated improvement in the students' awareness of and beliefs about bioenergy, biological resources, and metal resources. Moreover, we have expanded our research into a joint Japan–Korea project. The project provided the students in both countries an excellent opportunity to consider the possibilities for establishing a sustainable global society.

In this chapter, the current situation for science lessons that broaden sustainable society and the development of the lesson models in Japan is introduced.

22.2 Understanding of Key Concepts on Sustainable Development

The starting point for promoting ESD was the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro, Brazil in 1992. The basic action plan for ESD described in Chapter 36 of Agenda 21, which was established by the conference, is as follows: "*Both formal and non-formal education is indispensable to changing people's attitudes so that they have the capacity to assess and address their sustainable development concerns. It is also critical for achieving environmental and ethical awareness, values and attitudes, skills and behavior consistent with sustainable development and for effective public participation in decision-making. To be effective, environment and development education should deal with the dynamics of both the physical/biological and socioeconomic environment, and human (which may include spiritual) development should be integrated in all disciplines and should employ formal and non-formal methods and effective means of communication.*" (UNCED 1992).

After announcing this agenda, the need for ESD has gradually been recognized in Japan. Some pilot schools, including UNESCO network schools, have tried to organize ESD classes by advancing environmental education, intercultural education, peace education, human rights education, etc. However, these trials did not significantly spread because the government's education policy for ESD was not formulated at that time. Subsequently, a worldwide trend of promoting ESD reached its peak after the year 2000. After the World Summit on Sustainable Development (WSSD) in Johannesburg, South Africa in 2002, the United Nations adapted the proposal for a Decade of Education for Sustainable Development (DESD) from 2005 to 2014 to popularize the idea of sustainable development, and UNESCO requested member nations to formulate an enforcement plan for ESD. With this as a turning point, a liaison committee, organized by governmental offices including the Ministry of Education, Culture, Sports, Science and Technology (MEXT), formulated an enforcement plan for DESD in 2006 as a guideline for ESD.

According to the enforcement plan, the goals of ESD are: "*1) everyone can enjoy the benefits of high-quality education, 2) the principles, values, and actions needed for sustainable development can be taken into all fields of education and learning, and 3) education and learning can bring the changing of people's actions for realizing a sustainable future in the aspects of environment, economics, and society.*" (Liaison Committee among Ministries and Agencies on UNDESD 2006). Nothing that the first goal is a prerequisite for promoting ESD, and the third goal is the actualization of ESD, the second goal should be concretized in the classroom situation. Therefore, the concrete goals of ESD provide opportunities for people to be able to: (1) understand and think about the principles needed for sustainable development, like preservation and recovery of natural environments, (2) form a sense of value with respect to these principles, and (3) acquire a power of action based on this sense of value.

Subsequently, the enforcement plan describes various principles needed for sustainable development; e.g., preservation and recovery of natural environments, preservation of natural resources, intergenerational equity, interregional equity, gender equality, social tolerance, reduction of poverty, a fair and peaceful society, etc. However, the key concepts contained in the principles are limited. In a report for ESD written by the National Institute for Educational Policy Research in Japan (NIER 2012), concepts like diversity, mutuality, limitation, equity, cooperation, responsibility, etc., are mentioned. The former three concepts relate to the natural, social, and economic environments surrounding human beings, while the latter three concepts relate to the will and action of human beings in groups, regions, societies, nations, etc. (Table 22.1). Moreover, according to the Guidelines for Instruction of Environmental Education (NIER 2007), concepts like circulation, diversity, ecosystems, symbiosis, preservation, respect for life, continuity of life, etc., are also mentioned.

In order to achieve the three above-mentioned concrete goals, it is important first to promote students' understanding of key concepts for sustainable development. In the research and practice of science lessons, concepts must be integrated with science, technology, society, and environment (STSE) issues, such as natural resources, energy, transport, electronics, food, health, cosmetics, medical treatment, biotechnology, etc. Indeed, literature on science lessons that use integration has

Table 22.1 Key concepts for establishing a sustainable society (NIER 2012)

Concepts related to natural, social, and economic environment surrounding human beings	
Diversity	Nature, culture, society, and economics consist of diverse entities differing in the aspects of origin, character, situation, etc., and diverse occurrences of phenomena
Mutuality	Nature, culture, society, and economics mutually influence each other, and substances, energy, and information are communicated and circulated among them
Limitation	The limited environmental factors and resources, such as substances and energy, sustain nature, culture, society, and economics with the irreversible changes taking place within
Concepts related to the will and action of human beings in groups, regions, societies, nations, etc.	
Equity	Sustainable society is based on interregional, intergenerational equity, fairness, and equality that guarantees fundamental rights and enjoys the blessings of nature, etc.
Cooperation	Sustainable society is constructed by people's various adaptations/harmonies and cooperation/collaborations corresponding to situations, interrelationships, etc.
Responsibility	The people who are responsible for focusing on the visions and changes/innovations of the future are the ones who create a sustainable society.

been gradually emerging (e.g., Grace and Byrne 2010; Burmeister and Eilks 2012). Consequently, science lessons focused on STSE issues can enter the limelight and serve as a new starting point for achieving ESD.

22.3 Making Appropriate Judgments on Science, Technology, Society, and Environment Issues

The goals and key concepts of ESD describe viewpoints for planning innovative science lessons. Deliberate and careful planning on how to make proper lesson contents and effective teaching strategies based on the given viewpoints must be introduced. In relation to this subject, Burmeister et al. (2012) described basic models for approaching sustainability issues in chemistry education, Model 1 adopts green chemistry principles for the practice of science education lab work; Model 2 adds sustainability strategies to the content of chemistry education; Model 3 uses controversial questions of sustainability for socioscientific issues, in order to drive chemistry education; and Model 4 integrates chemistry education into ESD-driven school development. Model 1 adopts chemistry experiments with an emphasis on sustainable development, such as microscale experiments and usage of less poisonous substances. Model 2 adds subject matter, in which it appears to utilize basic chemical principles for industrial applications like reducing usage of natural resources and exhaust of waste products. Model 3 sets scenes of decision-making on the topics like the use of biofuel and influences of controlled substances on the human body. Finally, Model 4 integrates chemistry education into school activities, such as saving water and economizing electricity. Through integration, chemistry education plays a part in enriching social awareness and involvement.

These models display proper ways of linking chemistry education and ESD. That is, Model 1 links learning activities for chemistry education to ESD, with the purposes of promoting understanding and consideration of concepts for sustainable development and of forming values in sustainable development. Model 2 links the contents of chemistry education to ESD, and has the same purpose as Model 1. Model 3 links the themes of chemistry education to ESD based on the understanding of concepts for sustainable development. The purpose is to enhance students' ability to make judgments and to enhance decision-making in a social context, and at the same time to form values in sustainable development. Model 4 links the themes, contents, and learning activities of chemistry education and ESD as a whole. The purpose of this model is to encourage students' power of action in their daily lives.

Model 3 has highlighted the promotion of students' abilities in judgment and decision-making as a research interest for science education since the Science-Technology-Society (STS) movement of the 1980s. Various curricula and modules for promoting students' abilities in judgment and decision-making have been developed up until now (e.g., American Chemical Society 1988; University of York Science Education Group 1994; Demuth et al. 2006). Moreover, various ideas on issues-based approaches, including decision-making processes, have been advocated. For instance, Hodson (1994) suggested four levels of sophistication: (1) appreciating the societal impact of scientific and technological change, (2) recognizing that decisions about scientific and technological development are in pursuit of interests, (3) developing one's own views and establishing one's own underlying value positions, and (4) preparing for and taking action. In a separate manner, Lewis and Leach's (2006) idea established a relationship between the understanding of the content knowledge of science and the ability to engage in reasoned discussion of socioscientific issues.

However, few studies have been done in the context of Japanese science education that promotes students' ability in judgment. Therefore, lesson models for chemistry topics and effective teaching strategies that promote ability in high school chemistry are proposed herein. With reference to the above-mentioned studies, the lesson models are focused on judgment ability intervening in decision-making processes. This ability is comprised of three phases: (1) recognize a science-related problem in connection with social and environmental issues, (2) think of possible solutions based on understanding of content knowledge, and (3) make appropriate judgments directed toward solving the given science-related problem and taking action. The lessons are integrated on the topics of bioenergy like biodiesel, biological resources like chitin and chitosan, and metal resources like iron. The lessons on the topic of biodiesel and iron were carried out for Japanese and Korean students as joint research while the lesson on the topic of chitin and chitosan was conducted for Japanese students only.

22.4 Lesson Model on the Topic of Biodiesel

22.4.1 Development of the Lesson Model

The utilization of bioenergy as a renewable energy source is a recent social issue in Japan and Korea. Biodiesel, as a kind of bioenergy, is an alternative diesel fuel. However, students do not have satisfactory understandings of certain things about bioenergy and biodiesel, and they lack the ability to judge energy-related social problems. A lesson model for high school chemistry on the topic of biodiesel is proposed herein, with the aim of promoting students' ability to judge social problems of energy supply. This lesson assesses an assumption that would influence the acquired knowledge of biodiesel in the direction of the ability in judgment.

The aim of this lesson model is to promote students' ability to judge social problems of energy supply by applying their knowledge of science through an improved model of the Berlin analog (Kirschenmann and Bolte 2006, 2007). The contents of the lesson are composed of the following items.

- Lecture (60 min): "Energy situation and development of bioenergy/biodiesel"
- Experiment (180 min): "Generation of biodiesel" and "Comparison of biodiesel and diesel as chemicals"
- Group discussion (90 min): "Evaluation of biodiesel and diesel as fuels from the standpoint of energy" and "Planning for the utilization of biodiesel."

Materials for the lecture, worksheets for the experiments, and evaluation sheets for the group discussions were developed. These instructional materials were modified based on the original Berlin model. Contents from Japanese and Korean school textbooks were incorporated into the materials and manual to serve as supplements and to facilitate easy use for Japanese and Korean students.

22.4.2 Trial of the Lesson Model

The lesson model was carried out with 21 Japanese and 19 Korean students in 11th grade for 2 days in August 2011.

Lecture: The lecture covered the topic of world energy consumption, including in Japan and Korea, dependence on fossil fuels, reserves and price of crude oil, amounts of CO_2 exhaust, and the latest trends in the development of renewable energy around the world like bioenergy. Moreover, lectures on oils, fats, and fatty acids and the generation of biodiesel by transesterification of colza oil with methanol were presented to the students.

Experiment: Students' activities in this part included synthesis of biodiesel and measurement of calorific values, viscosities, and flash points among colza oil, biodiesel, and diesel (see Appendix). A chemical comparison of biodiesel and diesel was also conducted.

Group Discussion: Biodiesel and diesel were evaluated as fuels from the standpoint of energy. Moreover, the students discussed a plan to utilize biodiesel for a certain town. Discussion focused mainly on both the advantages and disadvantages of biodiesel for the promotion of bioenergy, as students themselves took on the role of consumers.

22.4.3 Evaluation of the Lesson Model

First, the appearance of ability in judgment was evaluated through two questionnaires and a group discussion. Regarding the questionnaire given to the students before and after the lesson, reasons for agreeing with or opposing the construction of facilities for energy supplies like fossil fuels, wood, biodiesel, biogas, wind, solar batteries, and nuclear power were enumerated. The number of reasons showed an increase of about 1.5 times per student after the lesson (Fig. 22.1). Specifically, after the lesson on energy supply facilities that use biodiesel was discussed, the number of reasons increased by about 1.8 times for Japanese students and 1.9 times for Korean students. The nature of the reasons was varied (Fig. 22.2). For instance, not only was the ecological aspect identified, but also reasons related to aspects of science (chemistry) and technology. These reasons increased after the lesson. Moreover, an aspect of sustainability also appeared significantly. These results show that students could sufficiently provide reasons for judging the possibilities for biodiesel as energy.

Another questionnaire was given to students after the lesson. When the prompt: "Write down ten criteria that are important to your assessments of the two kinds of fuel, i.e., biodiesel and diesel," was presented, various criteria from the standpoints of usefulness, cost, easiness of and prospects for manufacturing, responsible concern for the environment, fuel efficiency, etc., were raised (Fig. 22.3). Subsequently, assessment ratings for the two kinds of fuel were determined by the following rules:

– Choose five of the ten criteria that you want to use for the assessment. Determine the importance or the weighting factor of each criterion by allocating a total of 20 points to the chosen criteria.

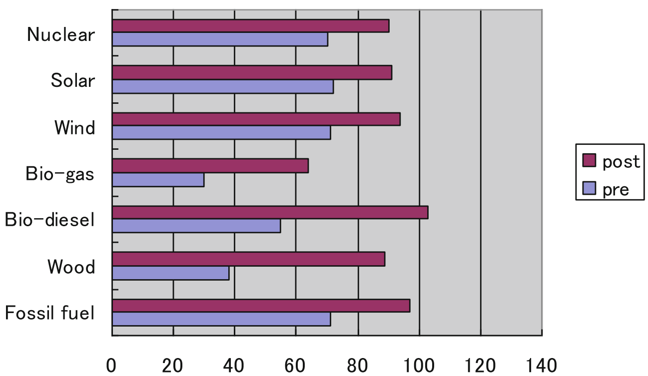


Fig. 22.1 Number of reasons for agreement and opposition (Japanese students)

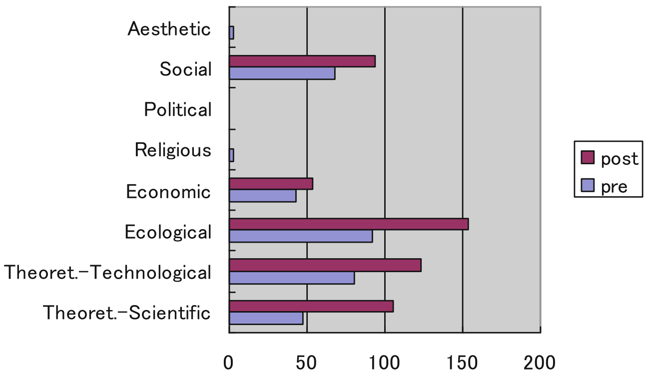
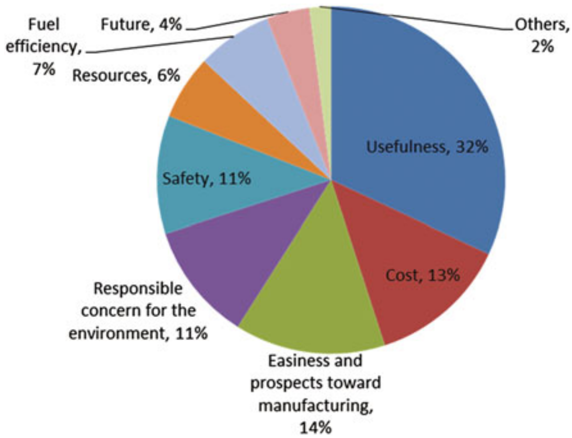


Fig. 22.2 Number of reasons from different standpoints (Japanese students)

Fig. 22.3 Criteria for assessing biodiesel and diesel as fuels (Japanese and Korean students)



– Assess biodiesel according to each criterion and allocate it a grade (5 = very good to 1 = inadequate).
– Calculate the weighted grades by multiplying the grade of the respective criterion by the weighting factor. Then, sum up the weighted grades. In order to calculate the "final grade," divide the sum of the weighted grades by 20.
– In order to assess diesel, use the same rule as that for biodiesel fuel.

The average of the "final grades" for Japanese students was 3.3 for biodiesel versus 2.7 for diesel, and that for Korean students was 3.5 for biodiesel versus 2.7 for diesel. Biodiesel clearly had higher assessments.

Moreover, the students discussed the plan to utilize biodiesel in a certain town as an example. Their sketches of the plan based on the discussion were indicative of various standpoints, such as the environment, the economy, the technology, and sustainable community. For instance, a female Japanese student who was conscious of the environment in the town paid attention to the cooperation between agriculture and the utilization of biodiesel. Her description was: "*The people cultivate corn and extracted oil. After the extraction, the dregs of the corn are also used as feedings of livestock, and then the dung of livestock is used as fertilizer for corn. The people should build a cycle like this to develop an ecological town that does not produce waste.*"

Second, acquired knowledge was evaluated through the Concept Map drawn by the students. Terms demonstrating knowledge of the raw materials and properties of biodiesel, e.g., colza oil, renewable energy, and carbon neutral, increased remarkably in number for both groups of students after the lesson. This type of knowledge can be understood as connecting different categories of knowledge, and as the formation of networks of knowledge, e.g., "*Bioenergy → Biomass → Utilization of waste → Waste treatment → Reduction of* CO_2 *exhaust*" *and* "*Biodiesel → Vegetable oil → Plant →* CO_2 *→ Environment → Carbon neutral.*"

Finally, regarding the relation between judgment and acquired knowledge, eight students who formed a practical plan for utilizing biodiesel from comparatively various viewpoints were watched. Each student individually mentioned common words, such as "environment" and "newness," in their responses, as shown in the evaluation tools (Table 22.2).

The lesson model was able to promote students' ability to judge energy-related social problems, not only from the perspective of environment, economy and society, but also science and technology. At the same time, significant relations between students' ability in judgment and their acquired knowledge of the scientific properties of bioenergy and biodiesel surfaced.

22.5 Lesson Model on the Topic of Chitin and Chitosan

22.5.1 Development of the Lesson Model

Chitin and chitosan are natural polymer compounds obtained from shells of crab and prawn. They belong to the group of polysaccharide, along with starch, cellulose, etc. Research into chitin and chitosan has been promoted for about 30 years. Currently, they are used for health food, antibacterial agents in clothes, cosmetics (shampoo, milky lotion, etc.), medical treatment materials (artificial skin and suture string), agricultural materials, wastewater treatment materials, etc., and have become one of the most widely used chemical substances in our daily lives. Chitin and chitosan are introduced as chemical substances with bright prospects by Japanese high school chemistry textbooks. However, the development of the lesson model on the topic of chitin and chitosan has hardly advanced. This study proposes a lesson model on chitin and chitosan for Japan, aimed at promoting students' ability to judge how they utilize these chemical substances in their daily lives.

The aim of this lesson model is to promote students' ability to judge the propriety of utilizations of chitin and chitosan by applying their knowledge of science. The contents of the lesson are composed of the following items.

Table 22.2 Relations between ability in judgment and acquired knowledge

Appearance of ability in judgment				Acquired knowledge
Evaluation tools	Group discussion: planning for the utilization of biodiesel	Questionnaire 1: criteria of the assessment of biodiesel and diesel	Questionnaire 2: reasons for an agreement with or opposition to the construction of facilities of energy supply	Concept map: knowledge about bioenergy and biodiesel
Student A	The people cultivate corn and extracted oil. After the extraction, the dregs of the corn are also used as feedings of livestock, and then the dung of livestock is used as a fertilizer for corn. The people should build a cycle like this to develop an ecological town that does not produce waste	**Environment**, **resources (reserves)**, combustibility, efficiency, weight, time for manufacture, viscosity, easiness of manufacture, price, safety	Agreement: **earth friendly,** good efficiency Opposition: requirement of much time	**Environment**, corn, plant, colza oil, it can be worked a car, revitalization of a town
Student B	The people set up a filling biodiesel station	**Burden for environment**, easiness of production, fuel consumption viscosity, limit or not (future), cheap	Agreement: **good for environment**, reduction of waste Opposition: high cost, no precedent because of the newness	**Good for environment**, new energy, diesel, light oil, motorbike, methanol solution

– Chemical structure of chitin and chitosan

1. Lecture (30 min)
2. Activity: “Making of molecular models” (60 min)

– Raw material and manufacturing process of chitin and chitosan

3. Lecture (30 min)
4. Lab experiment: “Formation of chitin and chitosan” (60 min)

– Features and use of chitin and chitosan

5. Lecture (30 min)
6. Lab experiment: “Anti-mold examination” (60 min), “Aggregation of dirt and collection of heavy metal ion” (60 min), and “Making of chitosan film used as a semipermeable membrane” (60 min)

– Gathering information on chitin and chitosan

7. Activity: “Gathering information from web sites” (30 min)
8. Study tour: “Manufacturing factory for chitin and chitosan” (1 day)

– Evaluation and utilization of chitin and chitosan

9. Classroom discussion and presentation: "Evaluation of the propriety of utilizations of chitin and chitosan" (60 min)

Materials for the lecture, worksheets for the experiments, and evaluation sheets for the classroom discussion and presentation were developed and utilized.

22.5.2 *Trial of the Lesson Model*

A lesson model was conducted for 18 students in 11th and 10th grade for 3 days in July 2009.

First day: Lesson contents 1–4 and a part of content 6 were performed. In content 1, the lecture on high molecular compounds, polysaccharides, polymerization, and the structure of chitin and chitosan was given to students. In content 2, the knowledge acquired from the lecture was confirmed by making molecular models as a student activity (Fig. 22.4). In content 3, the lecture on crab shells, which had initially been considered waste but now serve as the source of an important biomass, was presented. Then, a method of forming chitin from shells (removal of calcium and protein) and also a method of forming chitosan from chitin (deacetylation) were explained to the students. In content 4, the students made chitin and chitosan powder from a kind of crab (Fig. 22.5). In a part of content 6, students examined chitosan's controlling effect on the proliferation of mold by adding chitosan solution to the agar medium.

Second day: Contents 5, selected parts of content 6, and content 7 were conducted. In content 5, the lecture on various uses of chitin and chitosan was given to the students. In content 6, an experiment on aggregation of protein solution in water (for instance, the solution of skimmed milk) from chitosan solution was performed. Then, the students made chitosan beads from the solution, and colorized the beads with heavy metal ions (Cu^{2+}, Ni^{2+}, Co^{2+}) as a chelate complex (Fig. 22.6).

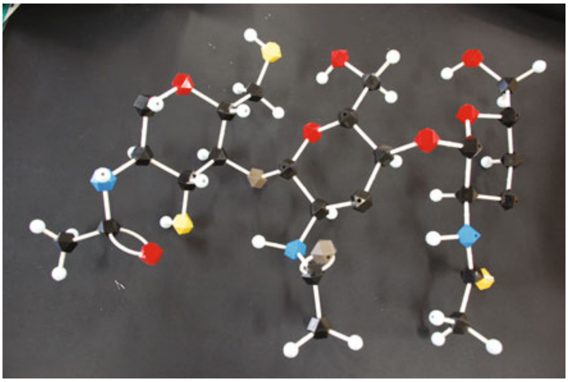


Fig. 22.4 Molecular model of chitin

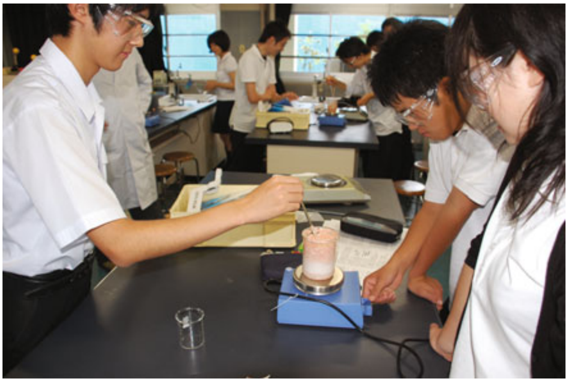


Fig. 22.5 Formation of chitin from crab shells (removal of calcium)

Fig. 22.6 Formation of a chelate complex by using chitosan beads

Moreover, they made chitosan film from the solution. In content 7, they collected information about chitin and chitosan using related web sites.

Third day: Contents 8 and 9 were implemented. In content 8, a factory tour was organized, and manufacturing and research sites for chitin, chitosan, and glucosamine were inspected (Fig. 22.7). In content 9, the possibilities for the use of

Fig. 22.7 Factory tour: crab shells as a raw material of chitin and chitosan

chitin and chitosan, and the propriety of their utilization as a healthy food were discussed.

22.5.3 Evaluation of the Lesson Model

Through the concept map, words associated with chitin, chitosan, and glucosamine were enumerated by the students before and after the lesson. The number of words increased by around 16 words per student after the lesson, while it had been around eight words per student before the lesson. The contents of the words show that the students acquired not only knowledge of basic chemistry concepts but also knowledge of the application and utilization of chemistry. Relations between the words show that students were able to connect the categories of knowledge and form networks of knowledge (Fig. 22.8).

Using a questionnaire, the students wrote freely on the possibilities for the use of chitin and chitosan after the lesson. About 80 % of students expressed a number of ideas about chitosan controlling the proliferation of mold and that, therefore, the water permeability of chitin sponges makes them a useful material for medical treatment. One of the students had the original idea that the best use of the above-mentioned characteristics would be application to the development of mats for pool locker rooms. Then, the propriety of chitosan's utilization as a supplement for obesity prevention was freely written about by the students (Gräber 2009). About 60 % of students expressed the similar idea that it was unnecessary to use the supplement for individual body balance. One of the students answered: "*Chitosan would not have to be used because it might obstruct not only assimilation of fat but*

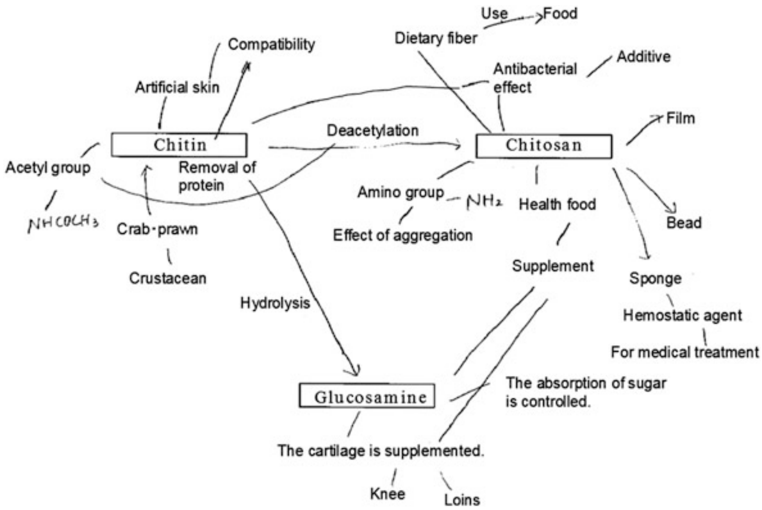


Fig. 22.8 Student's concept map: network of the knowledge on chitin, chitosan, and glucosamine

also that of fat-soluble vitamins." Students made appropriate individual judgments based on the knowledge of science that they acquired through the lesson.

22.6 Lesson Model on the Topic of Iron

22.6.1 Development of the Lesson Model

A material iron has widespread importance for our lives. Many machines, buildings, and life goods are made of iron. Moreover, a large amount of natural resources and energy sources, such as iron ore, coal and water, are needed for the production of iron. Therefore, we can understand the utilization of materials in today's life and society by paying attention to iron, and consider a direction for the development and the utilization of materials in the future. A lesson model on the topic of iron for high school chemistry is proposed herein, aimed at promoting students' ability to judge utilizations of iron. This study examines an assumption that influence students' ability in judgment to creative representations on natural phenomena.

The aim of this lesson model is to promote students' judgment abilities based on the knowledge of the features of iron. The contents of the lesson are composed of the following items.

- Lecture (120 min): "Iron: raw materials, manufacturing, utilization, and history"
- Experiment (120 min): "Metal plating on iron sheet and corrosion protection by plating on iron sheet"
- Study Tour (half day): "Steelworks"
- Activity (180 min): "Gathering information on iron and other materials for automobiles using web sites" and "Evaluation of utilization of iron and other materials for automobiles."

A manual for the lecture, worksheets for the experiment, and evaluation sheets for the activity were developed and utilized.

22.6.2 Trial of the Lesson Model

The lesson model was carried out with 36 Japanese students and 30 Korean students in 11th grade for 2 days in January 2011.

First day: lectures and study tour were carried out. First of all, the lecture on "What kinds of materials is an automobile made from?" was given in order to foster student interest in the topic of iron. Then, the lecture about (1) the raw materials for iron, (2) the manufacturing of iron, that is, the actual manufacturing process and the saving of energy and reduction of carbon dioxide, (3) the utilization of iron: types of use, alloy, protection against corrosion, and recycling of iron, and (4) history of iron. In parts of content (2), reduction of iron oxide with hydrogen instead of coke was demonstrated in a teacher experiment. During the study tour, steelworks was inspected and information about iron was gathered.

Second day: lesson experiments and an activity were conducted. The experiment on metal plating (tin, zinc, and nickel) on iron sheets was performed (Fig. 22.9). Then, the corrosion protection of plating on iron sheets was tested with a potassium ferrocyanide solution. After scratching it with the tip of a nail and dropping sodium chloride solution on it, color changes were compared (Fig. 22.10). In the activity, information about iron and other materials for automobile components was collected using web sites. Then, possibilities for the utilization of iron and other materials were discussed as a group activity, and models of future automobiles made from prospective materials were creatively sketched as an individual activity.

22.6.3 Evaluation of the Lesson Model

In the case of terms related to iron, as enumerated by the students, those terms demonstrating knowledge about the physical properties of iron increased

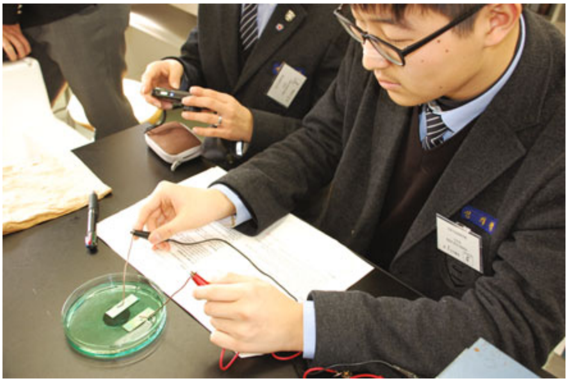


Fig. 22.9 Metal (Tin, Zinc, and Nickel) plating on iron sheet

Fig. 22.10 Corrosion protection of plated iron sheet

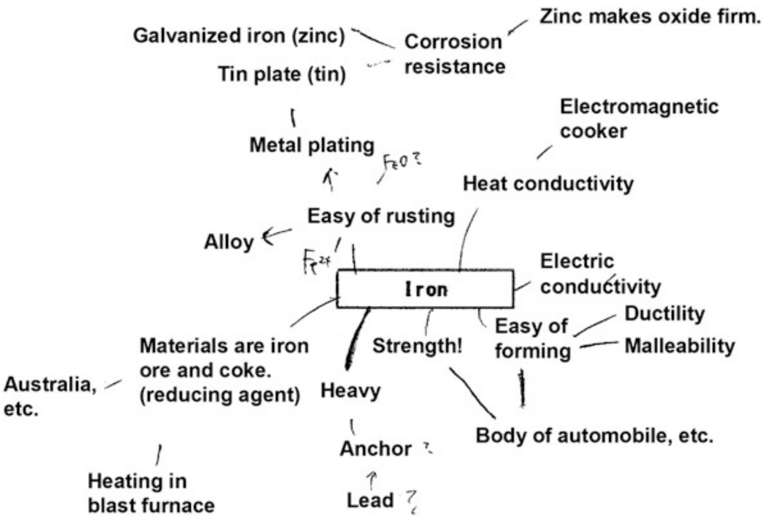
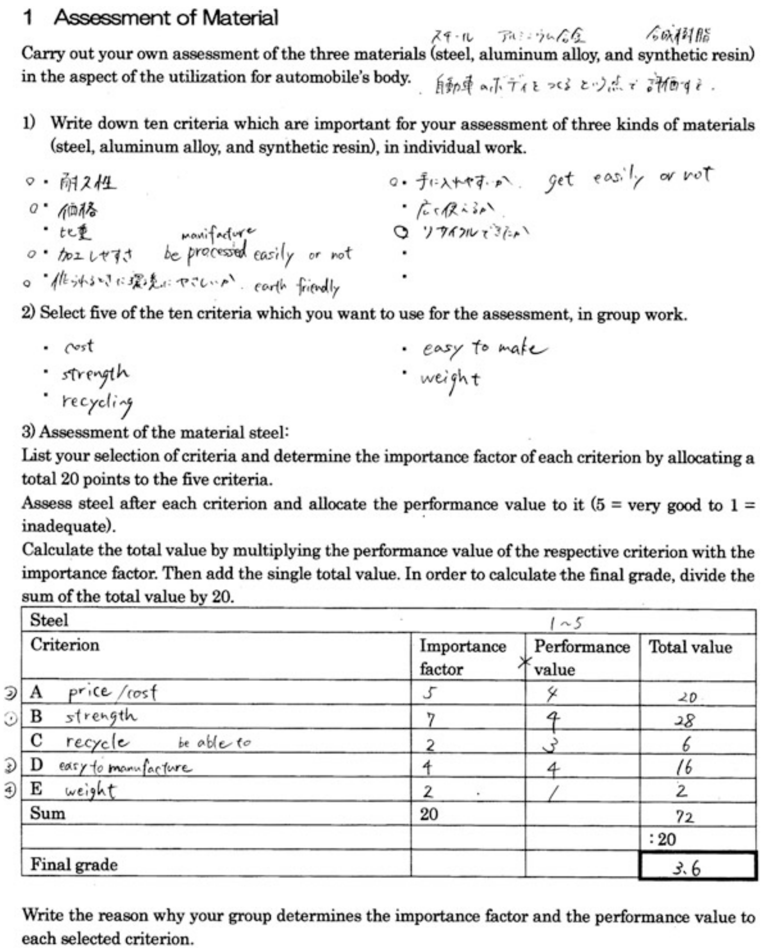


Fig. 22.11 Acquisition of knowledge about physical properties of iron (after the lesson)

remarkably in number among Japanese and Korean students after the lesson. The number of related terms enumerated per student was about 1.9 times higher for Japanese students and 2.5 times higher for Korean students. This type of knowledge can be understood as connecting different categories of knowledge, and as the formation of networks of knowledge (Fig. 22.11).

Regarding the assessed materials (steel, aluminum alloy, and synthetic resin) from the standpoint of utilization for automobile bodies, about 43 and 32 % of the assessment criteria enumerated by Japanese and Korean students, respectively, were related to the physical properties of the materials (specific gravity, strength, hardness, durability, forming, etc.) (Question 1 in Fig. 22.12) (Fujii et al. 2009). Then, the performance value assigned by the students' assessments displayed their judgment based on acquired knowledge of the physical properties and other features (price, recycling, etc.) of materials (Question 3 in Fig. 22.12).

In the case of materials selected in rough sketches for use in the parts of future automobiles, eight students showed creative representations, including originality, practicality, sensibility, and/or inclusiveness (Finke et al. 1992). For instance, a female Japanese student, whose creative representation displayed originality, calculated final grades that were higher for synthetic resin, as well as steel, in the assessment of materials (Fig. 22.13). Thus, students' representations were based on the judged value of materials' features, including their physical properties. A relation between students' creativity and judgment ability related to the features of materials, including iron, was found by this lesson.



1 Assessment of Material

Carry out your own assessment of the three materials (steel, aluminum alloy, and synthetic resin) in the aspect of the utilization for automobile's body.

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自動車のボディをつくるという点で評価する。

1) Write down ten criteria which are important for your assessment of three kinds of materials (steel, aluminum alloy, and synthetic resin), in individual work.

- 耐久性
- 価格
- 比重
- 加工しやすさ be processed easily or not (manufacture)
- 作られるさいに環境にやさしいか。earth friendly
- 手に入れやすいか。get easily or not
- 広く使えるか。
- リサイクルできるか
-
-

2) Select five of the ten criteria which you want to use for the assessment, in group work.

- cost
- strength
- recycling
- easy to make
- weight

3) Assessment of the material steel:

List your selection of criteria and determine the importance factor of each criterion by allocating a total 20 points to the five criteria.

Assess steel after each criterion and allocate the performance value to it (5 = very good to 1 = inadequate).

Calculate the total value by multiplying the performance value of the respective criterion with the importance factor. Then add the single total value. In order to calculate the final grade, divide the sum of the total value by 20.

Steel		1 ~ 5	
Criterion	Importance factor	× Performance value	Total value
A price/cost	5	4	20
B strength	7	4	28
C recycle be able to	2	3	6
D easy to manufacture	4	4	16
E weight	2	1	2
Sum	20		72
			: 20
Final grade			3.6

Write the reason why your group determines the importance factor and the performance value to each selected criterion.

Fig. 22.12 Worksheet assessing automobile materials (Omission of assessment of aluminum alloy and synthetic resin in Question 3)

22.7 Remarks

Innovative lessons in chemistry education that are effectively linked to ESD can advance students' knowledge of the science of energy and natural resources, and also promote their abilities in making appropriate judgments on STSE issues. These abilities reflect students' understanding of key concepts in sustainable development, such as limitations of energy and natural resources, and the mutual relationship that exists between the natural environment, economics, and society.

For further implementations of this study, we suggest some points directed toward developing effective lessons. First, it is crucial to choose topics that are highly relevant

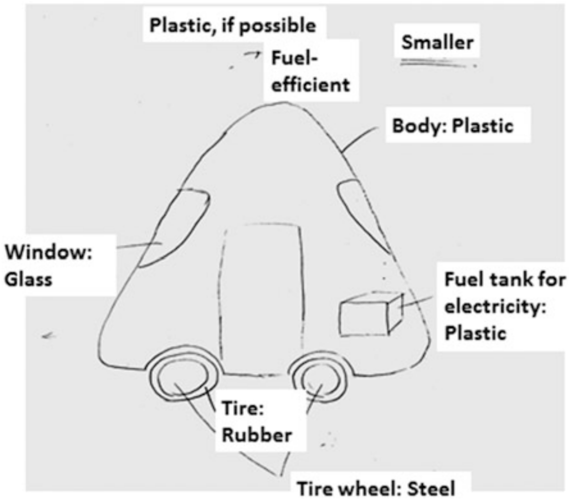

Fig. 22.13 Materials of some parts of a future automobile

to students. These topics will raise their awareness concerning STSE issues, and promote understanding of problems related to science. Second, it is also important to integrate within the lesson several components, like lectures, experiments, and inspection tours of factories. Through this integration, students will be aware of the realities of both modern society and their daily lives. Finally, in order to promote students' ability to make appropriate judgments, it is necessary to provide appropriate learning situations in which they can apply their knowledge of science and display their creativity in addressing issues that will positively promote a sustainable society.

Viewed from the ideological perspective of science education herein, these linkages may demonstrate an important standpoint. Namely, they adapt the standpoint that the objective of science education is to enhance students' understanding of the nature of science as a way to contribute to the development of human society, and at the same time to promote reflection on the importance of science in human life. This standpoint demands that students develop general education skills represented in an individual's judgments and actions as a responsible member of society. As a result, they can take part in active decision-making that concerns society as a whole and contribute to creating a sustainable society in the future.

On the other hand, some of the lessons introduced in this chapter elucidate that a joint project between Japan and Korea can achieve a measure of success in promoting students' judgment ability on STSE issues. The project provides the students in both countries an excellent opportunity to consider the possibilities for establishing a sustainable global society. We expect that this project will become a platform to establish collaborations in science education research and practices in the coming of a new era in Asia.

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Appendix: Worksheets for the Experiments on Biodiesel

Synthesis of Biodiesel

Purpose: To synthesize biodiesel from waste cooking oil and verify the product.

Preparation:

Experimental instruments

□ graduated test tubes □ 50 mL beaker □ a pestle and mortar □ a dropping pipet

□ a rubber stopper □ a glass rod □ an electric balance □ a capillary

□ a wide-mouthed reagent bottle □ a spray □ forceps □ a hot plate

Materials

□ waste cooking oil □ methanol CH_3OH □ sodium hydroxide NaOH

□ Thin Layer Chromatography plate (TLC)

□ TLC coloring reagent (vanillin-sulfuric acid)

□ TCL eluent (heptane: diisopropyl ether: acetic acid = 15:10:1)

A: Synthesis of Biodiesel

Safety goggles!

Procedure:

□ Weigh out about 0.7 g of sodium hydroxide (NaOH) and grind into powder with a pestle in a mortar. Transfer grinded NaOH into a beaker, then add 20 mL of methanol to dissolve NaOH completely. (This is sufficient for 10 experiments)

□ Add 10 mL of waste cooking oil and 2 mL of methanol with NaOH from procedure 1 into a graduated test tube and top it with a rubber stopper.

□ Holding the stopper firmly with the thumb, shake vigorously up and down for 3 min. (Observation ①)

□ Let the test tube sit for 30 min. Observe that the mixture separates into two layers while leaving the stopper on the tube. (Observation ②)

□ The biodiesel layer will float on top. Read the scale to measure the amount of biodiesel obtained. (Observation ③)

Observations:

□ ______________________________

□ ______________________________

□ __________ mL (What can be said from this result?) ______________

B: Verification by elution

Procedure:

① Add about 10 mL of eluent in a wide-mouthed reagent bottle and put the lid on. Wait for a while to let the eluent vapors saturate the air in the bottle.

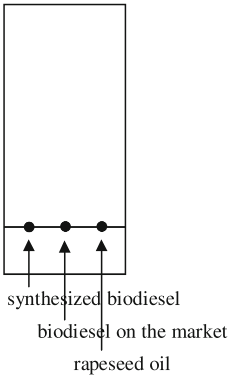
② Draw a straight line 1.5 cm from the bottom edge on a TLC plate with a pencil. (Make sure not to scrape off the thin layer on the plate.)

③ Spot 3 kinds of materials on the line drawn. See the figure on the right. Place the synthesized biodiesel on the left, biodiesel on the market in the center, and the cooking oil alone on the right.

④ Slowly place the TLC plate with 3 spots in the reagent bottle with eluent using forceps.

⑤ Remove the TLC plate when the eluent front reaches about eight-tenths of the plate.

⑥ Place the plate in the draft chamber and spray vanillin-sulfuric acid on it.



⑦ Place the plate on the hot plate in the draft chamber to heat and develop color. Record the result.

Notes:

Measurement of Viscosity

Purpose: To perform a quick measurement of viscosity of biodiesel, colza oil (raw material of biodiesel), and diesel oil, and compare the viscosity of the respective oils.

Preparation:

Experimental instruments

□ a glass tube with an iron ball in colza oil □ a glass tube with an iron ball in biodiesel

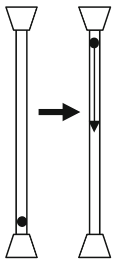
□ a glass tube with an iron ball in diesel oil

(a glass tube with 7 mm outer diameter and 1000 mm length, an iron ball with 4 mm diameter)

Procedure:

□ The three tubes with an iron ball and colza oil, biodiesel, or diesel oil are topped at both ends with rubber stoppers. Turn the tube with colza oil upside down so the end with the iron ball is on top. Start the stopwatch when the tube is turned completely, and measure and record the time in seconds until the iron ball reaches the bottom of the tube.

□ Perform the same procedure with biodiesel and diesel oil.



Results:

	Falling Time [s]		
	Colza oil	Biodiesel	Diesel Oil
1st			
2nd			
3rd			
Average			

Conclusion: What can be said from the results?

Discussion: Examine the viscosity of different kinds of liquid fuel. What is the advantage of liquid fuel with low viscosity?

Measurement of Calorific Value of Biodiesel and Diesel

Purpose: To obtain the calorific values and calculate the calorific values per unit volume of biodiesel and diesel oil.

Preparation:

Experimental Instruments:

□ an Erlenmeyer flask (500 mL) □ a stand, a bearing ring □ a thermometer

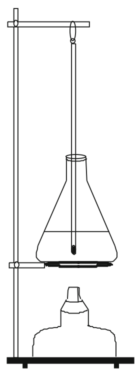
□ a graduated cylinder □ an electric balance □ forceps □ a stopwatch

Materials:

□ an alcohol lamp with biodiesel □ an alcohol lamp with diesel oil □ distilled water

□ a box of matches

Procedure:



□ Put 200 mL of distilled water in an Erlenmeyer flask and assemble the stand as shown on the right. Fix the bearing ring that supports the flask 11.5 cm from the surface of the bench surface.

□ Light the alcohol lamp with biodiesel and adjust the flame size to 2–3 cm by turning the wick up or down by the forceps, then put out the fire. Perform the same procedure on the alcohol lamp with diesel oil to adjust the flame size.

□ Weigh out the two alcohol lamps and record the weight before combustion.

□ Light the alcohol lamp with biodiesel and place it under the flask just beneath the thermometer, then start the stopwatch.

□ Record the temperature every 30 s. Be careful that the flame does not flicker with wind.

□ Put the lid on the lamp to put out the flame after 7 min.

□ Continue recording the temperature every 30 s for 2 min after the flame is put out.

□ Weigh out the alcohol lamp and record the weight after combustion.

□ Repeat steps ④–⑧ using the alcohol lamp with diesel oil.

Results:

1. Weight of Alcohol Lamps

Table 22.3

Liquid fuel	(a) Weight before combustion [g]	(b) Weight after combustion [g]	(c) Combusted mass [g] ($c = a - b$)
Biodiesel			
Diesel oil			

2. Water Temperature Change

Table 22.4

Time [min]	Temperature [℃]		Time [min]	Temperature [℃]		Time [min]	Temperature [℃]	
	Biodiesel	Diesel		Biodiesel	Diesel		Biodiesel	Diesel
0			3.5			7.0		
0.5			4.0			7.5		
1.0			4.5			8.0		
1.5			5.0			8.5		
2.0			5.5			9.0		
2.5			6.0					
3.0			6.5					

3. Record anything you noticed such as appearance of combustion.

Conclusions:

□ With the result shown in Table 22.3 and density, calculate the combusted volume of each liquid fuel.

Table 22.5

Liquid fuel	(d) Density [g/cm^3]	(e) Combusted mass [g] ($e = c$)	(f) Combusted volume [cm^3] ($f = e/d$)
Biodiesel	0.88		
Diesel oil	0.81		

Record calculation process:

□ With the result shown in Table 22.4, calculate the temperature increase and calorific values with combustion of biodiesel and diesel oil. Then, calculate the calorific value of each fuel per unit volume.

Table 22.6

Liquid fuel	(g) Temperature increase [℃]	(h) Calorific value [J]	(i) Calorific value per unit volume [J/cm^3] ($i = h/f$)
Biodiesel			
Diesel oil			

*The following formula is generally used to calculate calorific value:

When the temperature of a material with the specific heat of c [J/℃ g], mass of m [g] increased by T [℃],

The heat absorbed by the material Q [J] = mcT.

In this experiment, the specific heat of water is 4.18 [J/℃ g], and the mass of the water is 200 [g]. So Q [J] = $200 \times 4.18 \times T$

An instance of calculation:

Calorific Value $200 \times 4.18 \times 23.6 = 1.97 \times 10^4$

$200 \times 4.18 \times 18.6 = 1.55 \times 10^4$

Calorific Value per unit volume $1.97 \times 10^4/1.34 = 1.47 \times 10^4$

$1.55 \times 10^4/1.16 = 1.34 \times 10^4$

Discussion: What conclusion can be drawn from the results of calorific values per unit volume (Table 22.6) and the recorded appearance of combustion?

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