THE ANNALS OF EDUCATIONAL RESEARCH
〈Vol.46 March 2019〉

Development of an energy and environmental education program dealing with social issues

Masafumi Yamashita, Eiji Okamoto, Kazuyuki Nishiyama, Shinya Tanaka,
Masaru Nakamura, Takanori Tsutaoka, Ko Tomikawa

Abstract: In the 3rd grader of junior high school, we propose a new subject "resources and energy" dealing with social issues. Through this subject, we aim to foster the ability to think from a multifaceted and integrated viewpoint. We conducted a questionnaire survey whether students understand about scientific or social terms related to energy in the next year. The degree of understanding of the students who learned the program was high. And there were many students who thought that social issues could be solved by science and technology in future in comparison with groups that did not study this program.

1 Introduction

In " Science", which is a subject at the course of study in Japan, students learn scientific knowledge about environmental problems and energy. In particular, field one Content-(7) of "Science", that topic is " Science, Technology and Humans", has come to learn about the relationship between the use of energy resources and scientific and technological developments with human life.

However, according to the questionnaire survey of TIMSS 2015, there are improvements from past surveys on the interest, motivation, significance and usefulness of studying science as awareness of junior high school students in Japan, but comparing the international average, the proportion of positive opinions is low (fig.1). This is pointed out as a problem of current science education in Japan.[1)]

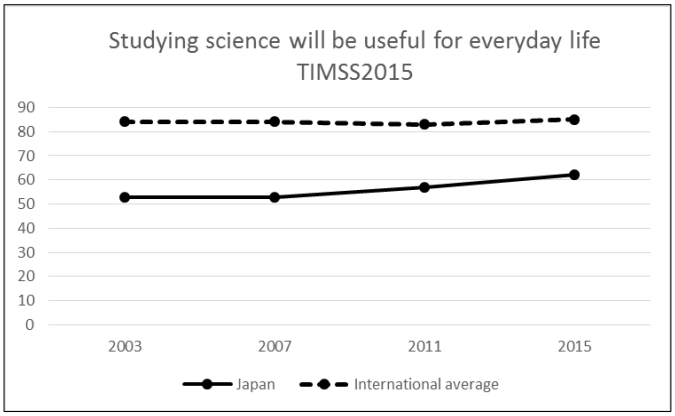


Figure 1 The questionnaire survey of TIMSS 2015

As a teaching material, dealing with the fact that modern society is supported by science and technology, and dealing with social issues will be a solution to this problem. Regarding social issues, it is important to analyze topics in multifaceted viewpoints and to make judgments on their own, in addition to scientific understanding. And development of science and technology and its use are useful for solving the issues, and expectation from society is great. Also, in the school education, it is important to

cultivate attitudes to think and act continuously for the future.

In Japan, energy self-sufficiency rate is low, and most of resources and energy are dependent on imports. Also, in economic activities and daily life, we use a lot of energy including electricity. Especially as the daily life becomes more convenient, energy consumption is increasing. Since the accident at Fukushima Daiichi Nuclear Power Station, energy problems such as nuclear power generation safety and carbon dioxide emissions from thermal power generation are becoming increasingly serious social issues.

The Agency for Natural Resources and Energy has set S + 3E of Safety, Energy Security, Economic Efficiency and Environment as the basic viewpoint of the energy policy. With regard to energy issues, it is necessary to consider critical and comprehensive consideration based on these policies.[2)]

Specifically, by teaching materials such as energy policies and economic effects, changes in consumer society due to the development of science and technology, it can be expected to students' ability and attitudes to scientifically consider based on data and comprehensively grasp them.

We also think that the usefulness of science can be felt by learning that society has become more convenient due to the development of science and that knowledge and skills of science are necessary to solve future problems.

When Hiroshima University High School, Fukuyama, received the designation of Super Global High School [SGH], we developed a new subject "Disaster prevention, Resources and Energy" to be taken in the third grader of junior high school. The overall objectives are as follows.[3)]

> To enable students to take an active interest in natural disasters and disaster prevention, resource and energy use, while also cultivating their fundamental abilities to multifaceted and critically analyze by actively exploring issues. To enable students to foster an attitude that students collaboratively construct disaster prevention and a sustainable society.

The purpose of this research is to measure and examine the effect by developing curriculum of this new subject “resources and energy” and practicing it.

2 New subject " Resources and Energy "

The new subject "Resources and Energy" is a subject that junior high school third graders learn in 35 hours. The teaching materials are based on the content of the 7th unit “Science, Technology and Humans” of the junior high school course of study “Science” in Japan. Its main content is to learn the scientific basic knowledge about energy and resources and to think about future science technology and society in the context of current situation in Japan.

The annual plan is as follows. In actual, classes are held in 2 hours a week in the second half of the year.

Table1 Instruction plan of “Resources and Energy”

month	units	contents
Oct	Chapter 1：Use of Energy 1. Various Energies and Its Change (1) Energy change	・Energy conversion and conversion efficiency ・Specific heat, how heat is transferred, the nature and use of thermal energy

	(2) Life and energy	· Historical matters related to development etc. of steam engines · Trends in utilization of human beings and energy · Changes due to the era of world energy consumption and energy consumption per person
	2. Use of electric energy	· Comparison of various power generation
Nov	(1) Various power generation	· Renewable energy · Distribution of power plants and high voltage transmission
	(2) Power generation and transmission	
	(3) Use of new energy	· Examination of output of power plant · Comparison of facility utilization rate · Power supply composition in Japan (energy mix) · Balance of supply and demand · Storage · Fuel cell
	3. Use of radiation and nuclear energy	
	(1) atom and radiation	· Radioactive isotope and radioactive decay, half-life, kind of radiation
Dec	(2) Utilization of radiation	· Characteristics of radiation · Use in medical, industrial, agricultural, etc. · Unit of radiation · Natural radiation and artificial radiation · Amount of radiation and influence
	(3) Structure of nuclear power generation and social issues	· Fission, fission products · Issues of nuclear waste
	Chapter 2 : Utilization of Resources	
	1. Resource utilization and energy ~ thermal energy and carbon dioxide emissions of fuels ~	· Use of chemical reactions and heat · Comparison of calorific value at fuel combustion and carbon dioxide emissions · Household environmental accounting booklet
Jan	2. Utilization of metal resources	
	(1) Various metal resources	
	(2) Metal smelting and energy	· Uneven distribution of resource production areas and reserve-to-production ratio · Dependence on the imports of Japanese resources · Refining and recycling
Feb		· Finite resources of metal resources and urban mines, recycling and 3R movement
	Chapter 3 : Toward a Sustainable Society	· Invention and use of electric light, change in life
	1. Science and technology and human Lives	· Comparison of electric energy consumption and features of filament lamp, fluorescent lamps and LED
	(1) Life and electric energy	
Mar	(2) Life and technology	· Current status and challenges of energy consumption in Japan · Energy Conservation
	(3) Society and technology	· Contribution of science and technology to society
	【Group activities】 ~ Power supply configuration after 20 years ~	· Proposal on "What is the structure of power supply in Japan after 20 years?"
	(4) Toward Effective Utilization of Energy 【Research Learning】	

3 Characteristic teaching materials

(1) Chapter 1 : 1-(2) Life and energy

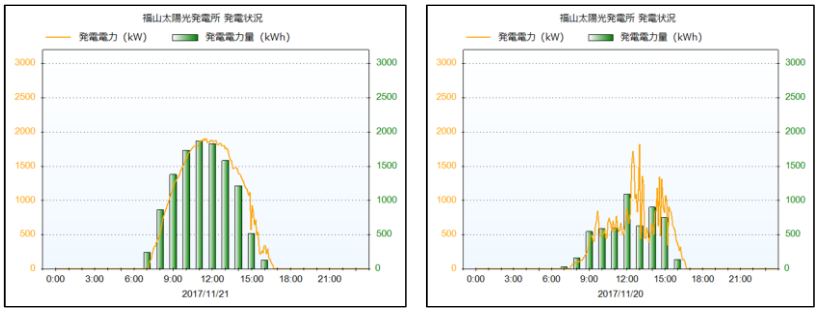
We deal with as a transition of the use of energy, the primary industrial revolution that light industries developed according to the invention of the steam engine, the secondary industrial revolution that shifted to heavy chemical industry by the use of electricity and petroleum, the tertiary industrial revolution by the use of nuclear energy. We deal with social scientific matters like this. So enable students to understand that the use of human energy has advanced to the development of energy sources with high energy density.

(2) Chapter 1 : 2 Use of electric energy

Electricity is familiar to students, even among energy use. Therefore, we deal with the power supply configuration in Japan, with a focus on the current state of power supply. For example, at the Fukuyama Solar Power Station, there are 3000 kW facilities, but since the annual power generation amount is 3.68×10^6 kWh, the facility utilization rate is 14%. The same is true for wind power generation, but it is 80% for thermal power plants. Through such comparisons, we will develop the concept of the power generation method.

Power supply and demand must always be balanced. If this balance is lost, the frequency of voltage becomes unstable and damage may occur industrially. In 2018, a blackout occurred in Hokkaido where the power station stopped due to the earthquake.

Power generation by natural energy such as solar power generation is also unstable. Students think by using power generation graph of Fukuyama Solar Power Station (fig.2) and learn by experiencing the difficulty of supply according to change in demand, using hand generators. Also, it turns out that technological development including electricity storage is useful for effective utilization of natural energy. In addition to this, enable students to understand energy mix as a way of thinking about Japanese energy policy stance.



(a) a sunny day 2017/11/21 (b) a cloudy day 2017/11/22

Figure 2 power generation graphs of Fukuyama Solar Power Station one day

(3) Chapter 1 : 3. Use of radiation and nuclear energy

In the field one Content-(7) of “Science”, it described the properties and use of radiation should also be touched on. We increase the content such as the nuclear structure, isotopes, radioactive decay, half-life of nuclei, and start learning from the nature of atoms. After that, we deal with nuclear fission, nuclear power generation and nuclear waste.

(4) Chapter 3 : 1-(1) Life and electric energy

Here we consider current situation in Japan based on the data published in the Energy White Paper of Japan 2016 Part 2. For example, looking at trends in energy consumption by sector from the final energy consumption and the trend of real GDP, the growth from 1973 to 2014 is 1.0 times for companies and business offices, 2.0 times for household sector, 1.7 times for transport sector. Since the oil shock, energy conservation is progressing mainly in the manufacturing industry, but in the household and transportation sectors, we see that the energy equipment and automobiles, etc. have proliferated and the number has increased greatly.

(5) Chapter 3 : 1-(3) Society and technology

In the last chapter, based on previous learning, students argue at each group about the composition of electricity supply in Japan after 20 years, and propose it. At that time, Figure 3 are shown so that the argument will deepen.

As a result, various arguments such as opinions at the economic point of view, opinions from the viewpoint of CO_2 reduction, assertions of necessity to improve self-sufficiency rate and assertions of increase in renewable energy were seen.

- Let's state your opinion firmly.
  Even in the same opinion, I will tell you your opinion and explain clearly how to agree.
- Let's show the reason as much as possible.
  In the current situation analysis, for example, there are several scientific, social and geographical perspectives.
- After listening to the opinions of others, please explain the question and conflict opinion accurately.
  Repeating the opinions of other people repeatedly, express your opinion about it, it is easy to understand.
- In social issues, opinions may be divided depending on where the values are placed. Let's deepen the argument by imagining what kind of background there is in the differences of opinions.

Figure 3 Points to be noted in argument

The three groups made the following arguments: Since there is a safety problem, nuclear power generation has to be 0%, it is necessary to focus on technological development on renewable energy, mainly by using thermal power generation. On the other hand, there were six groups that were mainly considering reduction thermal power generation and complement of power shortage by nuclear power generation from the issue of carbon dioxide emissions.

Figures 4 and 5 show the results of questionnaire survey after the group activity.

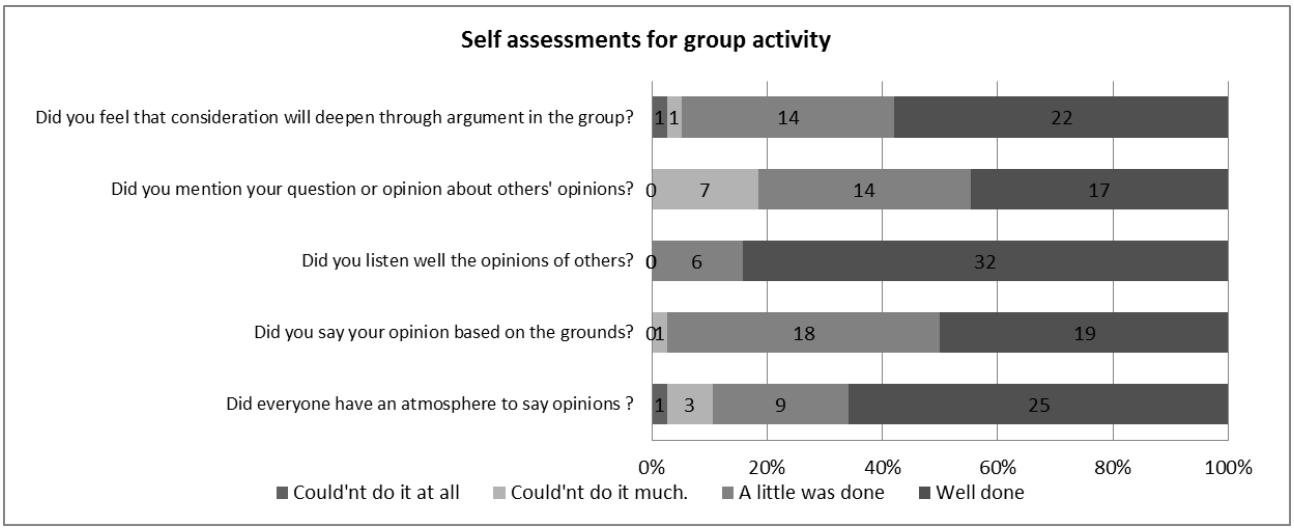


Figure 4 Self assessments for group activity in Chapter 3

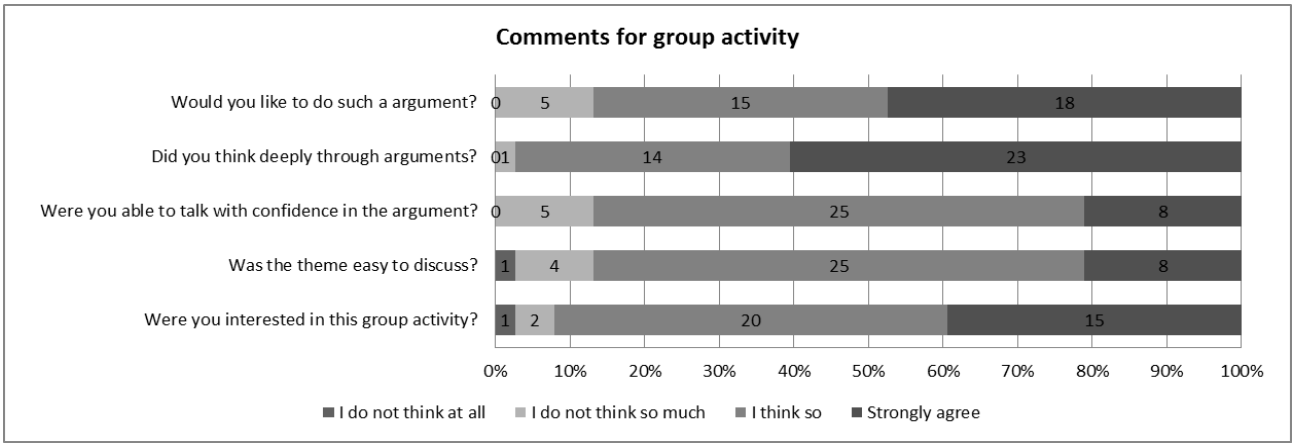


Figure 5　Comments for group activity in Chapter 3

Many positive opinions were seen in both survey results. Moreover, it can be said that multifaceted arguments were made based on data on this theme.

4　Effect on students

~ Questionnaire survey concerning energy problem before and after this program ~

In order to measure the effect of this program, we conducted a questionnaire survey in early September 2017, 117 junior high school 3rd grader students, and the end of May 2018, 201 high school 1st grader students.　The contents of the question are shown in Fig 6.　The results of the questionnaire survey are shown in the following table 2.　The obtained results were compared and analyzed in the following groups.

2017 A group　117 students in this group are 3rd grader junior high school student in 2017 and the survey was conducted before studying in 2017.

2018 A group　116 students in this group are the same members as 2017 A group, and the survey was conducted after studying.

2018 A * group　38 students of this group who belong 2018 A group, carried out the group activity of (5) above last year.
(Remaining 81 students of the 2018 A group, did not carry out the group activity of (5) above)

2018 B group　Students of this group who entered from the high school, have not learned this program. These students were studying "Science" at each junior high school.

Methods of analysis

Ⅰ In Q1, we consider choices as quantitative variables 1, 2, 3 and compare the average value of each group.

Ⅱ Compare Q2 to Q5, Q7 and Q8 by the correct answer rate for each group.

Ⅲ In Q6 and Q9 to Q15, we consider choices as quantitative variables 1 to 4 and compare the average value of each group.

In the question for which the average was obtained, student's *t*-test (two-tailed test) is performed and the p value of each is obtained.　Then, we investigate whether there is a difference at the

significance level 0.05 (5%).

Questionnaire survey on energy

1. For each of the following terms related to energy and environment, please answer the numbers that apply to you from the following choices
.【terms】
a Global warming b Fossil fuel c Circular economy d Renewable energy
e Food mileage f Energy mix g Methane Hydrate
h Primary energy and secondary energy i High level radioactive waste
j Deep geological repository k FIT (Feed-in Tariff) l Shale Gas Revolution
【choices.】① I do not know ② I know the words ③ I can explain the basic contents

2. Currently, what do you think about Japan's energy self-sufficiency rate?
Choose the closest value in the next choices.
① about 61% ② about 39% ③ about 18% ④ about 6%

3. What percentage do you think about the current Middle East dependence of Japanese petroleum and natural gas (LNG)? Choose the closest value in the next choices.
① about 25% ② about 50% ③ about 65% ④ about 80%
.

4. What do you think is the amount of power generated by thermal power generation in Japan generated in fiscal 2014? Choose the closest value in the next choices.
① about55% ② about 65% ③ about 75% ④ about 85%

5. Which of the following fuels do you think is the biggest generation of electricity in thermal power generation? Choose from the following choices.
① Petroleum ② Natural gas ③ Coal ④ Propane gas ⑤ Hydrogen

6. Do you think that Japan should use nuclear power in the future? Choose from the following choices.
① Increase the number of power stations to use ② Increase the number but gradually reduce
③ Utilize only facilities currently available ④ Should not be used in the future

7. According to the Ministry of the Environment, what is the proper temperature of air conditioner in summer? Choose from the following choices.
① 27℃ or more ② 25℃ ③ 23 ℃ ④ 20 ℃ ⑤ 20 ℃ or lower ⑥ I do not know

8. According to the Ministry of the Environment, what is the proper temperature of air conditioner in winter? Choose from the following choices.
① 27℃ or more ② 25℃ ③ 23 ℃ ④ 20 ℃ ⑤ 20 ℃ or lower ⑥ I do not know

9. Are you acting on energy conservation, such as turning off television and lighting frequently?
Choose from the following choices.
① do actively ② do to some extent ③ do not much ④ Not do at all

10. Do you think that technology can improve, and can be covered by "renewable energy (solar power, wind power, geothermal, etc.)" as a major energy source in Japan? Choose from the following choices.
① strongly agree ② think so ③ do not think so much ④ do not think at all

11. Do you think that Japan can significantly reduce greenhouse gas emissions such as carbon dioxide after 20 years? Choose from the following choices.
① strongly agree ② think so ③ do not think so much ④ do not think at all

12. Do you think that emission of greenhouse gases such as carbon dioxide is decreasing in the world after 20 years? Choose from the following choices.
① strongly agree ② think so ③ do not think so much ④ do not think at all

13. Are you interested in saving energy? Choose from the following choices.
① interested strongly ② interested ③ not very interested ④ not interested at all

14. Are you interested in electricity and energy issues? Choose from the following choices.
① interested strongly ② interested ③ not very interested ④ not interested at all

15. Do you want to do work related to energy or environment in the future? Choose from the following choices.
① strongly agree ② think so ③ do not think so much ④ do not think at all

Figure 6 Questionnaire survey on energy

The results of each question are shown in the table below.

Table2 Results of questions

Table2-1 Percentage of each choice Q 1

	choices	a	b	c	d	e	f	g	h	i	j	k	l
2017 A group	① %	0.0	0.0	14.5	0.0	33.3	79.5	46.2	7.7	58.1	75.2	95.7	79.5
	② %	1.7	33.3	65.8	41.0	46.2	17.9	39.3	63.2	33.3	19.7	3.4	16.2
	③ %	98.3	66.7	19.7	59.0	20.5	2.6	14.5	29.1	8.5	5.1	0.9	4.3
	Average	2.98	2.67	2.05	2.59	1.87	1.23	1.68	2.21	1.50	1.30	1.05	1.25
	SD	0.13	0.47	0.58	0.49	0.72	0.48	0.71	0.57	0.65	0.56	0.26	0.52
	Num	117	117	117	117	117	117	117	117	117	117	116	117
2018 A group	① %	0.0	0.0	8.6	0.0	12.9	58.6	34.5	2.6	40.9	51.7	60.3	74.1
	② %	2.6	22.4	59.5	15.5	53.4	34.5	49.1	36.2	42.6	29.3	21.6	21.6
	③ %	97.4	77.6	31.9	84.5	33.6	6.9	16.4	61.2	16.5	19.0	18.1	4.3
	AVG	2.97	2.78	2.23	2.84	2.21	1.48	1.82	2.59	1.76	1.67	1.58	1.30
	SD	0.16	0.42	0.59	0.36	0.65	0.62	0.69	0.54	0.72	0.77	0.78	0.54
	Num	116	116	116	116	116	116	116	116	115	116	116	116
2018 A* group	① %	0.0	0.0	13.2	0.0	10.5	57.9	26.3	5.3	37.8	50.0	47.4	76.3
	② %	0.0	15.8	52.6	10.5	55.3	31.6	50.0	34.2	40.5	15.8	23.7	15.8
	③ %	100.0	84.2	34.2	89.5	34.2	10.5	23.7	60.5	21.6	34.2	28.9	7.9
	AVG	3.00	2.84	2.21	2.89	2.24	1.53	1.97	2.55	1.84	1.84	1.82	1.32
	SD	0.00	0.37	0.66	0.31	0.63	0.69	0.72	0.60	0.76	0.92	0.87	0.62
	Num	38	38	38	38	38	38	38	38	37	38	38	38
2018 B group	① %	0.0	0.0	2.5	0.0	37.5	82.5	32.5	45.0	51.3	76.3	90.0	81.3
	② %	7.5	16.3	42.5	11.3	45.0	16.3	47.5	33.8	40.0	17.5	8.8	16.3
	③ %	92.5	83.8	55.0	88.8	17.5	1.3	20.0	21.3	7.5	6.3	1.3	2.5
	AVG	2.93	2.84	2.53	2.89	1.80	1.19	1.88	1.76	1.56	1.30	1.11	1.21
	SD	0.26	0.37	0.55	0.32	0.71	0.42	0.71	0.78	0.63	0.58	0.35	0.47
	Num	80	80	80	80	80	80	80	80	79	80	80	80

t .test p	a	b	c	d	e	f	g	h	i	j	k	l
2017A-2018A	0.646	0.064	0.02	1E-05	3E-04	7E-04	0.144	7E-07	0.006	4E-05	2E-10	0.444
2018A-2018B	0.141	0.29	6E-04	0.397	6E-05	1E-04	0.584	3E-13	0.048	2E-04	8E-08	0.236
2018A*-2018B	0.084	0.95	0.008	0.908	0.002	0.007	0.487	2E-07	0.04	0.002	2E-05	0.366

Table2-2 Correct answer rate [%]
Q2, Q3-1(petroleum) ,Q3-2(LNG), Q4, Q5, Q7,

	Q2	Q3-1	Q3-2	Q4	Q5	Q7	Q8
2017-A	33.3	85.3	6.0	12.1	9.5	73.3	29.3
2018-A group	54.3	80.2	9.5	30.2	27.6	66.4	38.8
2018-A* group	60.5	76.3	13.2	44.7	31.6	68.4	42.1
2018-B group	35.0	81.3	12.7	21.3	13.8	52.5	28.8

Table2-3 Percentage of each choice Q6, Q9-Q15

	choices	Q6	Q9	Q10	Q11	Q12	Q13	Q14	Q15
2017 A group	① %	8.6	8.6	17.2	6.9	3.4	11.2	9.6	0.9
	② %	19.8	64.7	50.9	29.3	26.7	75.0	50.4	6.0
	③ %	52.6	19.0	31.9	52.6	50.9	9.5	34.8	62.9
	④ %	19.0	7.8	0.0	11.2	19.0	4.3	5.2	30.2
	Average	2.82	2.26	2.15	2.68	2.85	2.07	2.36	3.22
	SD	0.67	0.56	0.71	0.63	0.58	0.50	0.64	0.41
	Num	116	116	116	116	116	116	115	116
2018 A group	① %	19.8	16.4	16.4	6.9	6.9	18.1	12.9	0.9
	② %	11.2	62.9	49.1	34.5	43.1	66.4	56.0	7.8
	③ %	47.4	15.5	31.0	50.9	40.5	11.2	23.3	56.0
	④ %	21.6	5.2	3.4	7.8	9.5	4.3	7.8	35.3
	Average	2.71	2.09	2.22	2.59	2.53	2.02	2.26	3.26
	SD	0.83	0.60	0.70	0.63	0.62	0.57	0.63	0.46
	Num	116	116	116	116	116	116	116	116
2018 A* group	① %	17.9	20.5	15.4	7.7	10.3	17.9	10.3	2.6
	② %	5.1	64.1	53.8	30.8	51.3	64.1	59.0	10.3
	③ %	48.7	7.7	25.6	48.7	30.8	15.4	28.2	46.2
	④ %	28.2	7.7	5.1	12.8	7.7	2.6	2.6	41.0
	Average	2.87	2.03	2.21	2.67	2.36	2.03	2.23	3.26
	SD	0.84	0.62	0.70	0.67	0.67	0.66	0.66	0.58
	Num	39	39	39	39	39	39	39	39
2018 B group	① %	18.4	16.3	13.8	6.3	6.3	17.5	8.8	1.3
	② %	5.3	57.5	35.0	30.0	16.3	53.8	57.5	12.5
	③ %	47.4	18.8	42.5	58.8	62.5	21.3	26.3	57.5
	④ %	28.9	7.5	8.8	5.0	15.0	7.5	7.5	28.8
	Average	2.86	2.18	2.46	2.63	2.86	2.19	2.33	3.14
	SD	0.75	0.64	0.72	0.62	0.60	0.67	0.61	0.49
	Num	80	80	80	80	80	80	80	80

t .test p	Q6	Q9	Q10	Q11	Q12	Q13	Q14	Q15
2017A-2018A	0.034	0.167	0.092	0.159	0.227	0.124	0.154	0.168
2018A-2018B	0.277	0.464	0.033	0.771	0.002	0.115	0.552	0.201
2018A*-2018B	0.975	0.43	0.122	0.679	0.001	0.292	0.536	0.471

As a result of the analysis of Q1(Table2-1), many students understand these terms at junior high school graduation stage, and there is no significant difference between 2018 A group and 2018 B group. However , in terms of current situation and policies in Japan, f “Energy mix”, h “Primary energy and secondary energy”, i “High level radioactive waste”, j ”Deep geological repository”, k “FIT (Feed-in Tariff)”, 2018 A group is higher than 2018 B group, significant difference was seen. As students learned about the current situation in Japan and problems of Japan on energy at the junior high school subject “Society”, students of 2018 B group were expected to be able to understand terms of f “Energy mix” and h ”Primary energy and secondary energy”, but there were many selectors of ① "I do not know". Also, in these questions, 2018 A group has a higher point compared to 2018 B group, however half of them have selected ① "I do not know" in the terms of f

and it can be said that there is a problem with fixing memory.（fig. 6） In addition, as seen in the terms f, j and k, it is a future task that some terms related to policy were answered by ① "I do not know" by the majority of the students.

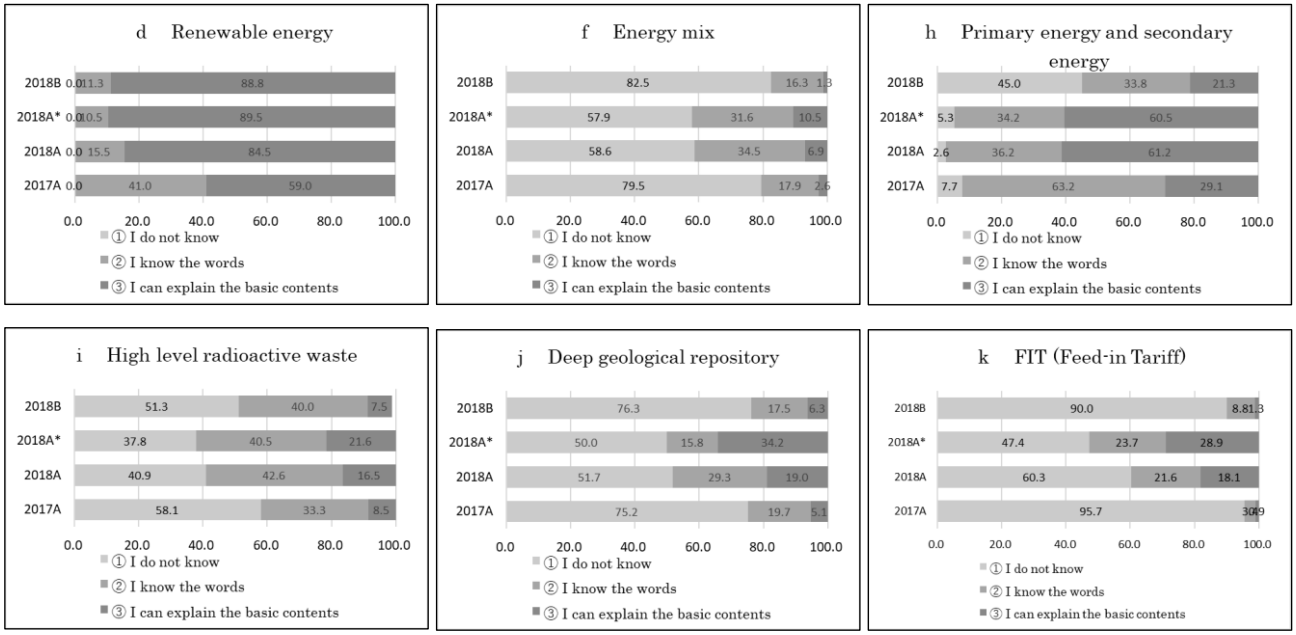


figure 6 Results of Q1

In the question about the current situation in Japan, the 2018 A group are over 10 % higher than the 2018 B group in 4 out of 7questions(Table2-2). However, it is a problem that the correct answer rate of Q3-2, Q4, Q5 has not reached 50%. Q6, Q9-15 are questions to ask about students' thoughts and actions. Comparing the 2018 A group and the 2018 B group, the significant differences were seen in Q10 and Q12(Table2-3,fig.7). Compared to the 2018 B group, many students of 2018 A groups thought that science and technology can solve social problems such as global warming in the future. From this point, through this program, it can be considered that students have come to think positively by combining science and technology and social problems.

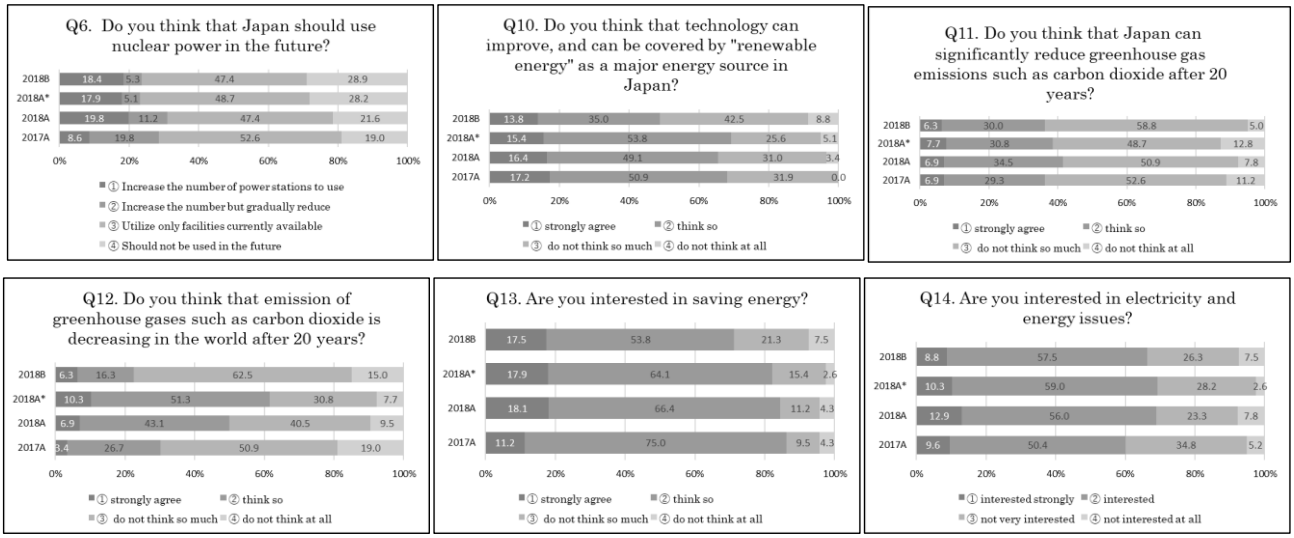


figure 7 Results of Q6, Q10-14

There were no significant differences in other questions, however, many questions regarding behavior were positive.

5 conclusion

Regarding social issues like resources and energy, it is important to think from a viewpoint of natural science and social science such as the current situation in Japan and international relations.

Based on the understanding of energy concept, we developed and practiced a new subject "Resources and Energy" aimed at nurturing the ability to think social issues from multifaceted viewpoint. In this new subject, we have developed teaching materials of electric power, and also of current situation and policies in Japan, as the theme related energy. As a group activity at the final stage, the students argued about "the composition of electricity supply in Japan after 20 years," and carried out activities to propose opinions. This theme is interesting for the students, and it was suitable for team activities.

Questionnaire survey at high school found that students who learned the program were more knowledgeable and interested about scientific concepts and social issues related to energy compared to students who did not learn. However, more than half of the students answered "I don't know" in relation to policies, and it is a future task to improve this.

References

1) Yoichi KIYOHARA,(2017).Based on the Relevance of Various Surveys on Science, SCIENCE EDUCATION MONTHLY2017/Nol.66/No.780. pp4-7.

2) Agency for Natural Resources and energy.(2018). *The New Strategic Energy*.pp.15

3) 広島大学附属福山中・高等学校.(2018).第 1 部　研究開発実施報告 平成 29 年度（第 3 年次）.中等教育研究紀要.pp31-41