An Educational Methodology for Sustainable Development

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Abstract: It is required to solve various environmental and social problems and achieve 'sustainable development (SD).' Education is critical for promoting SD. Here we approach 'education for sustainable development (ESD)' from the viewpoint of 'control.' First, we show the control system for SD, identifying necessary elements such as controlled objects, controlled variables and control objectives. Next, we provide a methodology of ESD, showing the procedure for creating educational programs as well as the educational elements that such programs should contain. Moreover, we present a case study, whose results have confirmed the validity of this methodology.

Keywords: sustainable development, education, control, stability.

1. INTRODUCTION

Nowadays, human beings are facing various environmental and social problems; for example, global warming, the destruction of ecosystems, an increase of areas where water supplies are insufficient, the tight supply-demand situation for oil and metals, unstable economies, income inequalities and conflicts. It is the ultimate challenge of the 21st century to solve these problems and achieve 'sustainable development (SD)' or 'sustainability.' United Nations clearly stated, "Education is critical for promoting SD" [1].

However, according to UNESCO, which has been designated as the lead agency to promote 'education for sustainable development (ESD),' "No universal models of ESD exist" [2]. Here we approach ESD from the viewpoint of 'control.' The reason why we have adopted this approach is that the achievement of SD implies "purposive influence toward a predetermined goal" [3], a general definition of 'control.' In this paper, we first show the control system for SD and then provide a methodology of ESD. Moreover, we present a case study, whose results have confirmed the validity of that methodology.

2. CONTROL SYSTEM FOR SD

When the achievement of SD is addressed as a subject, controlled objects, controlled variables, control objectives, and the purpose of control, which is necessary for deriving control objectives, are identified as follows [4]. Fig. 1 shows the schematic block diagram of the control system in which these elements are combined. Incidentally, "disturbances" are considered to be harmful influences on controlled objects caused by environmental and social problems. Examples of the disturbances are damage caused by environmental pollution, flood or landslide damage resulting from unbridled land development, and various kinds of damage caused by global warming.

"Controlled objects" are human activities which cause environmental or social problems that should be solved. The units of human activities can be assumed to be various, for example, activities performed by an individual, a family and a company, and human activities in a region and in a nation.

"Controlled variables" are the variables that belong to human activities and need to be controlled for solving the problems. From among them, eight important

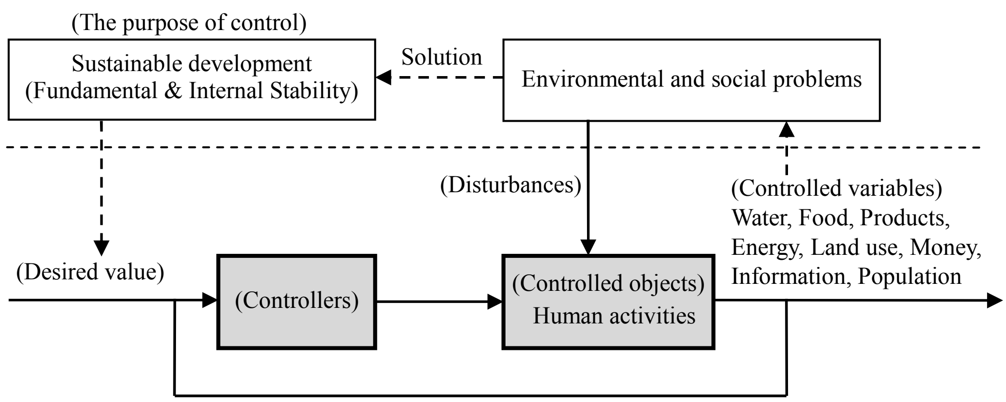


Fig. 1 The control system for sustainable development.

controlled variables, namely 'water,' 'food,' 'products,' 'energy,' 'land use,' 'money,' 'information' and 'population' have been selected [5]. Incidentally, the term 'products' means various manufactured or constructed goods such as clothes, machinery, cars, buildings and civil engineering works.

"The purpose of control" is identified as SD. In order to clarify the essence of SD, we have developed the model of SD in which 'stability' is centered (Fig. 2). This model shows that SD means 'achieving both the Fundamental Stability and the Internal Stability,' in order to accomplish the long-term well-being of all humankind, or ultimate end, within the finite global environment and natural resources, or absolute limitations. The 'Fundamental Stability' means environmental stability and a stable supply of natural resources, and it requires 'global environmental preservation and the sustainable use of natural resources.' On the other hand, the 'Internal Stability' means social and economic stability, and it requires the 'fulfillment of the basic conditions for human beings' well-being' such as health, safety, mutual help and self-realization.

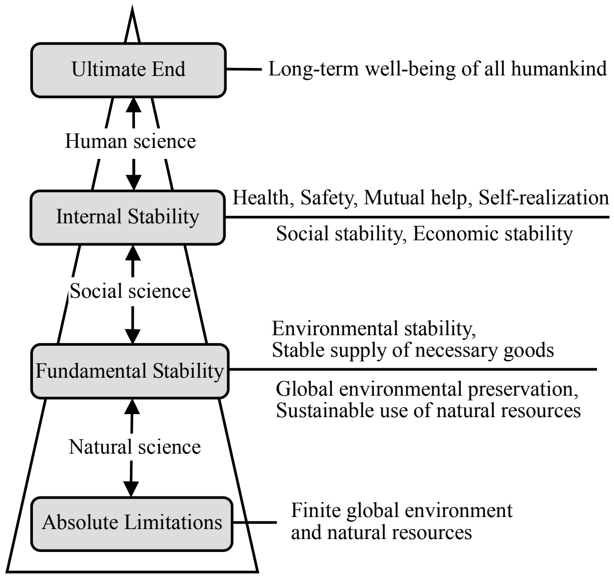


Fig. 2 The model of sustainable development.

After a controlled object and a controlled variable are identified, the desired value for the controlled variable is derived from the purpose of control. Finally, the "control objective" is required to adjust the controlled variable to the desired value.

3. EDUCATIONAL METHODOLOGY FOR SD

3.1 Function of ESD

In order to control human activities toward SD, 'people,' responsible for human activities, need to change their behaviors toward SD. 'Changes in people's behaviors,' for example, changes in their behavior patterns and lifestyles, and the utilization of environmental technologies, require people to have sufficient capacity and motivation to promote such changes. Therefore, the approach from the viewpoint of 'control' considers the function of ESD as follows: to increase people's capacity and their motivation to promote changes in their behaviors toward SD.

3.2 Methodology of ESD

When educational planners consider an ESD program, first of all, they show a proper control system in accordance with a given educational objective. This step requires identifying the following elements: 1) a controlled object, or human activities relating learners; 2) a controlled variable; 3) the desired value; 4) the environmental or social problems that should be solved. Fig. 3 shows an example of a control system in which these elements are identified.

Next, the program should be planned so as to contain as many educational elements that increase learners' capacity and their motivation to change their behaviors toward SD as possible. The following itemizes such educational elements [4].

Elements increasing learners' capacity

(1) Understanding a Controlled Variable and its Desired Value

A controlled objective is required to adjust a controlled variable to its desired value. Therefore, learners need to understand both the controlled variable and its desired value.

(2) Increasing Capacity to Plan Controllers

It is necessary for learners to plan controllers, or changes in their behaviors that enable the control objective to be achieved. Accordingly, their capacity to plan controllers should be increased.

(3) Increasing Capacity to Execute Controllers

Moreover, learners are expected to execute controllers in the real world. Therefore, their capacity to execute controllers should also be increased.

Elements increasing learners' motivation

(1) Recognizing the Relationship between the Controlled Variable and Problems

This element means recognizing that learners themselves are involved in the environmental or social problems. In other words, they have a sense of responsibility.

(2) Recognizing the Problems and Disturbances

Recognizing the problems means understanding about the problems that should be solved. Recognizing disturbances means perceiving harmful influences on the controlled object caused by the problems.

(3) Recognizing Benefits Accompanying Changes in Behaviors

This element means recognizing learners' direct benefits that accompany changes in their behaviors. 'Benefits' in this context include not only economic profits but also various factors which improve learners' quality of life such as improvements to their health.

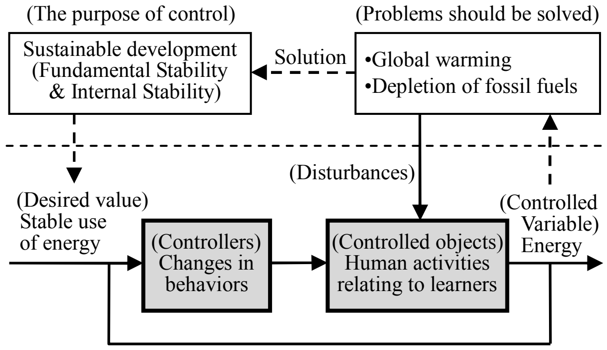


Fig. 3 An example of a control system for ESD.

4. CASE STUDY

4.1 Control system for the case study

We produced programs of ESD on the basis of the aforementioned methodology and put them into practice. We conducted a large number of energy educations in accordance with the control system that has already shown in Fig. 3. This control system shows that, in order to deal with 'global warming' and the 'depletion of fossil fuels,' 'energy' is identified as a controlled variable among 'human activities relating to learners,' and the 'stable use of energy' is set as the desired value. Incidentally, the 'stable use of energy' means the use of energy that can achieve the purpose of control, especially the 'Fundamental Stability.' That is ultimately regarded as the state in which the energy used by learners can be met only by renewable energy such as solar energy. In addition, controllers are considered as various 'changes in learners' behaviors' that promote energy saving and the utilization of renewable energy in order to meet their energy needs only by using renewable energy.

4.2 Program components

People's lives directly and indirectly involve using energy in different ways. Narrowing them down to the energy used in 'home' only, we have produced educational programs for the stable use of energy. The following activities are main components of such educational programs.

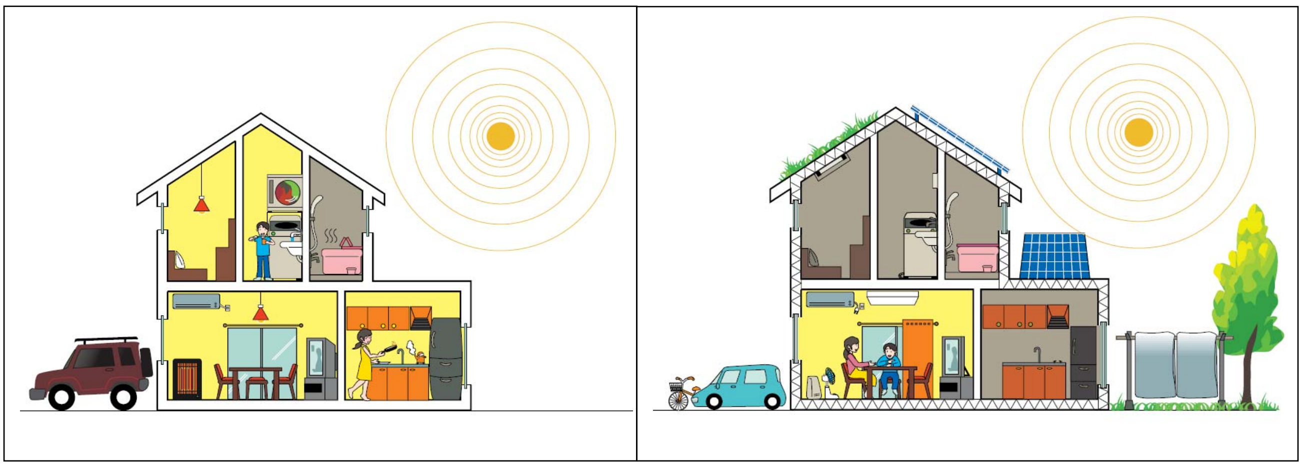
1) Find Eco-Lifestyles

In this activity, a pair of illustrations shown in Fig. 4 is used. First, the two illustrations, which depict "a home where energy is wasted (A)" and "a home where energy is used efficiently (B)," are distributed to each group. Members of each group look for the differences between the two illustrations, thinking about and discussing the reasons why the amount of energy used in these two homes are significantly different from each other, while comparing these with their own homes. About 10 minutes later, the representatives of the groups presented the results of the discussions one by one. Examples are "While the lights in A are light bulbs, those in B are fluorescent lights," and "While washing in A is dried in the drier, that in B is dried in the sun." Incidentally, there are over 20 differences between A and B.

"Find Eco-Lifestyles" relates to the 'elements increasing learners' capacity and motivation,' which are itemized in Chapter 3, in the following way. "A home where energy is wasted (A)" corresponds to a common controlled variable for learners, whereas "a home where energy is used efficiently (B)" corresponds to its desired value. Therefore, while comparing the two homes, learners can 'understand a controlled variable and its desired value.' At the same time, they can find controllers, namely changes in their behaviors, such as "to use fluorescent lights rather than light bulbs," or "to dry washing in the sun rather than in a drier." Accordingly, this activity also contributes to 'increasing capacity to plan controllers."

2) Measurement with Watt-Hour Meters

In this activity, the electricity consumption and standby power consumption of familiar electrical appliances are measured with watt-hour meters. In Fig. 5 (a), the electricity consumption of a light bulb and that of a fluorescent light are being gauged. In Fig. 5 (b), the



A: A home where energy is wasted　　**B**: A home where energy is used efficiently

Fig. 4 Find Eco-Lifestyles.

(a)

(b)

Fig. 5 Measurement with Watt-Hour Meters.

electricity consumption and standby power consumption of a television and a radio cassette recorder are being gauged.

Measurement with watt-hour meters clearly shows where and how much energy is consumed; therefore, it leads to ‘understanding a controlled variable.’ In addition, the measurement also shows effective ways of saving energy such as ‘changing from a light bulb to a fluorescent light’ and ‘pulling the plugs of unused appliances or using extension cords with “off” switches.’ Accordingly, it also contributes to ‘increasing capacity to plan controllers.’ Moreover, these watt-hour meters can convert electric energy into CO_2 emissions. Therefore, considering energy usage in close relation to global warming, learners can recognize ‘the relationship between a controlled variable and the problem.’ Furthermore, these instruments can also convert electric energy into electricity charges. Accordingly, learners can recognize the relationship between saving energy and saving money, in other words, ‘their direct benefits which accompany the control.’

3) Harmful Effects of Using Fossil Fuels

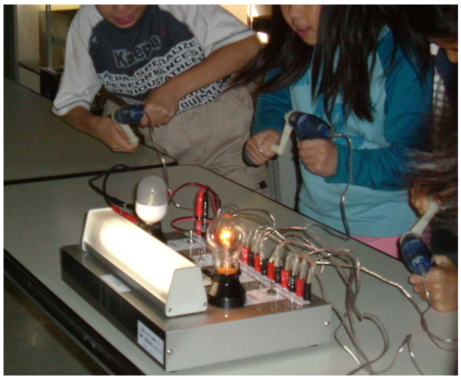
The majority of our energy usage that depends on fossil fuels, namely oil, coal and natural gas, causes global warming and the depletion of fossil fuels. It is feared that the progress of global warming will worsen its harmful influences such as a rise in sea levels and abnormal weather. On the other hand, the depletion of fossil fuels can cause social disorder due to the tight supply-demand situation for energy. In order to help participants understand and realize these causal relationships, we adopt participatory learning in the form of a quiz as well as the screening of audiovisual aids.

Understanding and realizing harmful effects of using fossil fuels mean recognizing ‘the relationship between the controlled variable and the problems’ as well as ‘the problems and disturbances.’ Recognizing these elements would increase learners’ motivation to change their behaviors.

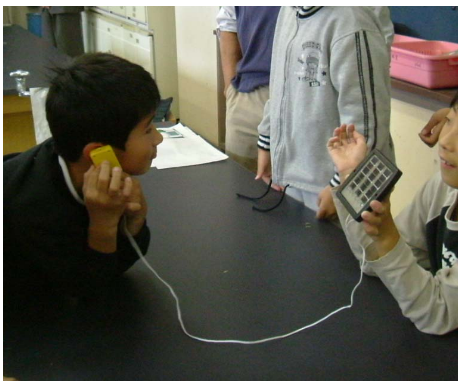
4) Experiments on Energy Saving and Utilizing Solar Energy

We often adopt experiments on energy saving and utilizing solar energy, which help participants realize the value of using environment-friendly technology. In Fig. 6 (a), participants are lighting a light bulb, fluorescent light and light-emitting diode (LED) light, using hand-cranked generators. This experiment can clearly show that a fluorescent light is much superior to a light bulb in energy efficiency and the energy efficiency of a LED light exceeds still more than that of a fluorescent light. In Fig. 6 (b), participants experience music, connecting a tiny solar panel to a music box.

These experiments help realize the effectiveness of using-technology ‘controllers’ such as “using fluorescent lights rather than light bulbs” and “utilizing



(a)



(b)

Fig. 6 Experiments on energy saving and utilizing solar energy.

solar panels." Therefore, they contribute to 'increasing capacity to plan controllers.'

5) Planning and Executing Actions

At the final stage in the education for the stable use of energy at home, learners are expected to actually improve their household energy usage. Therefore, it is significant for learners to make their own action plans for improving their household energy usage and carry these plans into execution.

'Planning and executing actions' contributes to 'increasing capacity to plan controllers' and 'increasing capacity to execute controllers.'

4.3 Results of education practices

Selecting several components from the above activities, we combined them into educational programs and put them into practice at schools and local communities. The following shows the results of school and social education practices.

1) Example of School Education

We provided a total of eight classes at five elementary schools and three junior high schools, in Kanagawa Prefecture, Japan. The educational program was mainly composed of three of the above-mentioned activities: "Find Eco-Lifestyles," "Harmful effects of using fossil fuels," and "Experiments on energy saving and utilizing solar energy." Therefore, this program contained the following educational elements from among the elements itemized in Chapter 3: 'understanding a controlled variable and its desired value,' 'increasing capacity to plan controllers,' 'recognizing the relationship between the controlled variable and problems,' and 'recognizing the problems and disturbances.'

We have measured the educational effects, using the sheets that were filled out before and after the classes [4]. In the sheet, we asked about the ten items shown in Table 1, which relate to people's attitudes toward their use of energy. These ten items can be classified into three groups: the items from No. 1 to No. 7 are connected with energy saving, No. 8 and No. 9 are related to the utilization of solar energy, and No. 10 is associated with self-sufficiency in terms of energy by both saving energy and utilizing solar energy. The learners responded to these ten items by choosing one of three choices: 'yes (○),' 'no (×)' and 'mean (Δ).' We processed the data on each item before and after the classes according to the following procedure: (1) integrated 'Δ' and '×,' (2) compiled a cross tabulation, (3) handled it by following the McNemar's law, and (4) performed a χ^2 (chi-square) test. As a result, among all ten items at both the elementary and junior high schools, we found the disparity in numbers of the learners who changed their choice after the classes between "from Δ or × to ○" and "from ○ to Δ or ×" (upon all, df=1, $p<0.01$). Table 1 shows the numbers of the learners who changed their choice and χ^2 values.

In the sheets that we distributed after the classes, we also asked the learners to write freely their impression of the classes. Although their impressions included various content, the most common content was their declaration of intention to improve their own use of energy. The number of the learners who wrote such statements amounted to 320, which accounted for over 50% of a total of 636 participants. After classifying these statements by point, we found the following three main groups: (1) 179 learners who declared they would save energy, for example, "I will not waste energy hereafter;" (2) 47 learners who showed the intention to use solar energy such as "I want to use electric appliances with solar cells;" (3) 32 learners who stated their desire to live in a house with solar panels. In addition to the above students, 36 learners described their recognition of the necessity to change their own behavior.

From the above results, we conclude that the classes have notably increased the learners' capacity and their motivation to improve their use of energy, concerning both energy saving and the utilization of solar energy.

2) Example of Social Education

From 2005 to 2006, we provided workshops for local residents of Asahi and Kanazawa Wards in Yokohama City, Japan. The program for the workshops mainly consisted of three of the aforementioned activities: "Measurement with watt-hour meters,"

Table 1 Each item's numbers of "Δ×→○" and "○→Δ×" and χ^2 values.

Item	Elementary schools (N=410)			Junior high schools (N=223)		
	Δ×→○	○→Δ×	χ^2	Δ×→○	○→Δ×	χ^2
1) Switching off the lights in unoccupied rooms	32	3	24.0	23	2	17.6
2) Switching off the TV when you are not watching	49	11	24.1	40	1	37.1
3) Avoiding stuffing food in the refrigerator	110	21	60.5	78	7	59.3
4) Walking or biking when going out nearby with family	64	10	39.4	47	1	44.1
5) Unplugging long-term unused electrical appliances	101	22	50.7	67	14	34.7
6) Minimizing the use of air conditioners	84	18	42.7	52	6	36.5
7) Using fluorescent lights rather than light bulbs	162	20	110.8	92	6	75.5
8) Using solar-powered calculators and watches	117	18	72.6	85	8	63.8
9) Using solar-powered battery chargers	135	20	85.3	75	4	63.8
10) Wishing to live in a house with solar panels	46	12	19.9	47	8	27.7

[Note] Upon all, df=1, $P<0.01$

"Harmful effects of using fossil fuels," and "Planning and executing actions." Therefore, this program contained all of the six educational elements that relate to increasing learners' capacity and motivation.

We have measured the educational effects, using the sheets that the learners filled out before and after the workshops. In the sheets, we asked about 20 items which relate to people's behaviors toward their use of energy; for example, "switching off the lights in unoccupied rooms," "avoiding stuffing food in the refrigerator," and "walking or biking when going out nearby." The learners responded to these 20 items by choosing one of the following six levels: 100%, 80%, 60%, 40%, 20% and 0%. '100%' means 'always behave in that way;' on the other hand, '0%' means 'never behave in that way.' Considering '100%' as 5 points, '80%' as 4, '60%' as 3, '40%' as 2, '20%' as 1, and 0% as 0, each learner totaled up the scores for the 20 items. We calculated averages for the total scores that 34 valid respondents filled in before and after the workshops. As a result, we found an improvement in the average score from 74.9 to 84.2. This improvement in the score was equivalent to a 102kg-per-year reduction in the emission of carbon dioxide per learner. Accordingly, we consider that these workshops have increased the learners' capacity and their motivation to improve their use of energy and in fact led them to distinctive changes in their behaviors.

5. CONCLUDING REMARKS

Our main findings and implications discovered in this paper are as follows. Chapter 2 showed the control system for SD and identified the elements that are required to form it. These results may encourage the science of 'control' to deal with the subject of accomplishing SD and sharply increase the contribution to it from this science. Chapter 3 showed the procedure for creating educational programs as well as the educational elements that such programs should contain. These results are equivalent to the methodology that is expected to play the role of a model for conducting ESD. Chapter 4 demonstrated practical examples of energy education based on this methodology. The results showed that the education practices have increased the learners' capacity and their motivation to improve their energy usage, which has confirmed the validity of that methodology. Accordingly, in order to mitigate global warming and the depletion of fossil fuels, the methods in the case study are expected to be widely used at education interfaces.

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