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Implementation of Energy Conservation Activities in a University and the Evaluation of their Results - Efforts by Doshisha University

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Abstract The present study discusses the energy conservation activities of Doshisha University; we examined changes in "energy consumption", "the comfort conditions of students", and "student attitudes toward energy saving" to discuss the "contribution of our activities to the environment", "the social responsibility of students", and "continuity". As a result, although there was an increase in the number of days on which lectures were delivered until the first week of August, 2008 (a one-day increase between 2008 and 2009), contrary to the assumption, a decrease was noted in the consumption of city gas in the university. As for the comfort condition of students, questionnaire surveys were conducted on energy conservation activities implemented until the summer of 2010, and the results identified the details of environmental problems associated with lecture classes: - In the summer season, there were decreases in "comfort levels expressed as temperatures" during lectures due to changes in room temperatures and humidity levels. - The environment for students to listen to lectures significantly varied depending on the college (campus), time, and classroom. - The environment was affected by the outdoor air to some extent, although the level of this influence became increasingly lower.

Keywords Energy, Conservation, University, Air conditioning, Questionnaire

1. Introduction

Since the oil shock in 1973, the Japanese government has implemented energy saving policies. The oil shock, a substantial decrease in the oil supply due to political instability in the Middle East, caused an energy crisis in Japan. Domestic laws related to energy were reviewed following the oil shock, including a revision of the "Law Concerning the Rational Use of Energy" (Energy Conservation Act established by the Ministry of International Trade and Industry)[1]. Global warning and other environmental issues have attracted attention in recent years, and energy conservation has become increasingly important in the accomplishment of environmental goals, including those stated in the Kyoto Protocol.

The official name of the Energy Conservation Act is the "Law Concerning the Rational Use of Energy", which was established in 1979 based on the "Heat Management Regulation" (1947)[1]. The revision, a shift from a law designed to only manage heat to that regulating energy including both heat and electricity, aimed to facilitate the effective use of fuel resources and contribute to the country's healthy economic development by reducing the consumption of fossil fuels or reliance on imported fuels.

Since the Kyoto Protocol entered into effect in 2005, there has been increasing public concern over greenhouse gas emissions and an awareness of energy conservation as an environmental measure. In this context, the Energy Conservation Act was revised to include a larger number of regulations applied to a wide area[2]. The Energy Conservation Act stipulates that the operators of facilities whose "total annual petroleum-equivalent consumption of heat and electricity is 3,000 kL or higher" be designated as "Type 1 Designated Energy Management Factories" and have an obligation: a 1% or higher annual mean reduction in "energy consumption per unit"[3]. Operators that continually fail to submit regular reports on the status of their energy consumption may be punished, including recommendations, the publication of their names, and penalties (fines). Since 2010, each operator of a facility has become responsible for energy management, and franchise operators that satisfy specific requirements have also been subject to similar regulations and measures[4].

In 2005, Doshisha University Kyotanabe College was designated as a "Type 1 Designated Energy Management Factory" in accordance with the former Energy Conservation Act, and the college became obliged to reduce its annual "energy consumption per unit" by a mean of 1% or higher as its goal. Since the revision of the Energy Conservation Act in

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2010, School Corporation Doshisha University as a whole has had to fulfill this obligation.

To accomplish this goal, the university has initiated various efforts to address environmental issues as an educational institution, including surveys on energy consumption, direct energy conservation measures, and environmental activities. One of these efforts is the environmental activity on air conditioner temperature control in the university implemented by the Energy Saving Promotion Committee consisting of teaching staff in collaboration with the Doshisha Eco Project, a student group[5]. Air conditioner temperature regulations have been introduced in the university: 28°C in the summer and 20°C in the winter.

The present study discusses the energy conservation activities of Doshisha University, a prestigious private university; we examined changes in "energy consumption", "the comfort conditions of students", and "student attitudes toward energy saving" to discuss the "contribution of our activities to the environment", "the social responsibility of students", and "continuity". The results of this study will serve as an index of energy conservation efforts implemented around the world.

2. Evaluation based on Energy Consumption

The following evaluation methods were used:

In the summer of 2008, air conditioner temperature control was introduced on a trial basis, and the temperature settings for air conditioners in the following four school buildings of the university were turned up by 1.8°C: the 2nd building of Chishin-kan and Mukoku-kan of Kyotanabe College and Shingaku-kan and Rinko-kan of Imadegawa College. Students who used these buildings took a questionnaire survey during their lunch break. Following the experiment that was conducted in the summer season, the air conditioning was set to 20°C in all school buildings on every campus in the winter of 2008. From that time on, questionnaire surveys were conducted in classrooms where teachers who served as members of the Energy Conservation Promotion Committee provided lectures, which increased efficiency in the survey. In response to the results of the experiment conducted in 2008, the air conditioning was set to 28°C in the summer and 20°C in the winter throughout the university in 2009 based on a formal decision. Temperatures and humidity levels were also measured in 2009, in addition to a survey involving four classrooms (two from each of the two colleges) conducted for the five days of a week. In 2010, the experiment continued under the same conditions: 28°C in the summer and 20°C in the winter. Some questions were asked at the beginning of the survey period, and the remainder of the questions was asked at the end of the survey; the survey was conducted once a week over a period of five weeks (five days in total).

2.1. Evaluation Methods

The study examined the effects of energy conservation efforts implemented by Doshisha University based on its energy consumption between 2005 and 2009.

Doshisha University, including the facility divisions of Kyotanabe and Imadegawa Colleges, has been conducting surveys on its energy consumption using measurement equipment. Kyotanabe College, in particular, has commissioned Kansai Electric Power Co., Inc. with the task of writing "annual reports on the results of surveys on energy consumption in Doshisha University Kyotanabe College" to report and disclose its activities to the government and public in response to the Energy Conservation Act. The present study examined the status of energy consumption at Doshisha University Kyotanabe College, based on the information included in the annual reports[6-9].

2.2. Changes in Energy Consumption

<Results of energy conservation efforts in 2008 and 2009>

The effects of air conditioner temperature control, an energy conservation activity, were most notably reflected in the consumption of city gas. This is because city gas contains "medium pressure gas", which is used to operate air conditioners. The study first discussed the status of gas consumption in recent years. As shown in Table 1, there has been an increase in the consumption of city gas at Doshisha University in recent years. However, since the university started to implement its energy saving efforts in 2008, there has been a decrease in the consumption of city gas - 5% year-on-year reductions.

First, a survey on the status of classroom use was conducted to examine whether or not the reduction was attributed to energy conservation activities. The status of classroom use, including the number of days on which lectures were delivered and classrooms were used as well as changes in room temperatures, affected energy consumption. However, in most facilities of the university, all air conditioners in one building were turned on or off at the same time, rather than having different temperature settings for each classroom, such that the two former conditions were disregarded. For this reason, the present study examined the effects of our energy saving activities by focusing on the relationship between changes in the number of days on which classes were held and energy consumption. As shown in Table 2, there was an increase in the number of days on which lectures were delivered until the first week of August, 2008 (a one-day increase between 2008 and 2009)[10]. However, contrary to the assumption, a decrease was noted in the consumption of city gas in the university, which supports the effects of the energy conservation activities (Table 3).

When air conditioning is used, the outdoor temperature significantly affects the room temperature. Data on temperatures in Kyotanabe City during the energy conservation period between 2005 and 2008 were obtained

(Figures 1 and 2)[11]. Considering the very high temperatures in the summer of 2008, when our energy saving efforts were implemented, and the mean temperature in the winter period as usual, including the past two years, the energy conservation activities were considered to be effective.

Table 1. Consumption of city gas (2003-2009)[6-9]

Year	2003	2004	2005	2006	2007	2008	2009
City gas[10^3 m^3]	1135	1230	1463	1507	1992	1884	1613
City gas[GJ]	51075	55350	65835	67815	89640	84780	72585

Table 2. Number of days in which lectures were delivered(2006-2009, Doshisha Univ.)[10]

Year	2006	2007	2008	2009
Number of days in which lectures were delivered[days]	156	156	167	168

Table 3. Energy consumption (2004-2009) (14)(15)(16)(17)

	2004	2005	2006	2007	2008	2009
Total energy consumption[GJ]	222226	238932	245681	269895	287118	274141
Changes in the consumption of city gas[GJ]		+16706	+6749	+24214	-4860	-12190

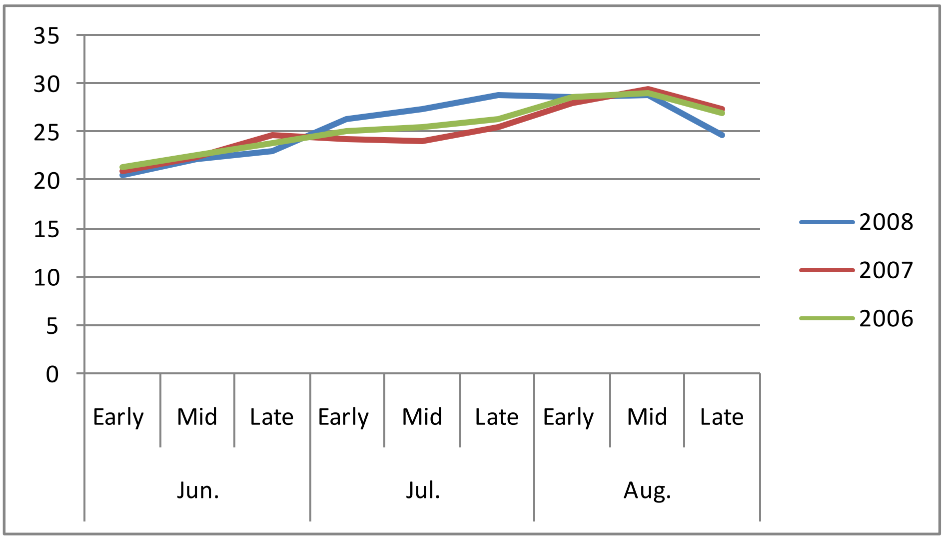

Figure 1. Changes in temperatures (Summer, Kyotanabe)[11]

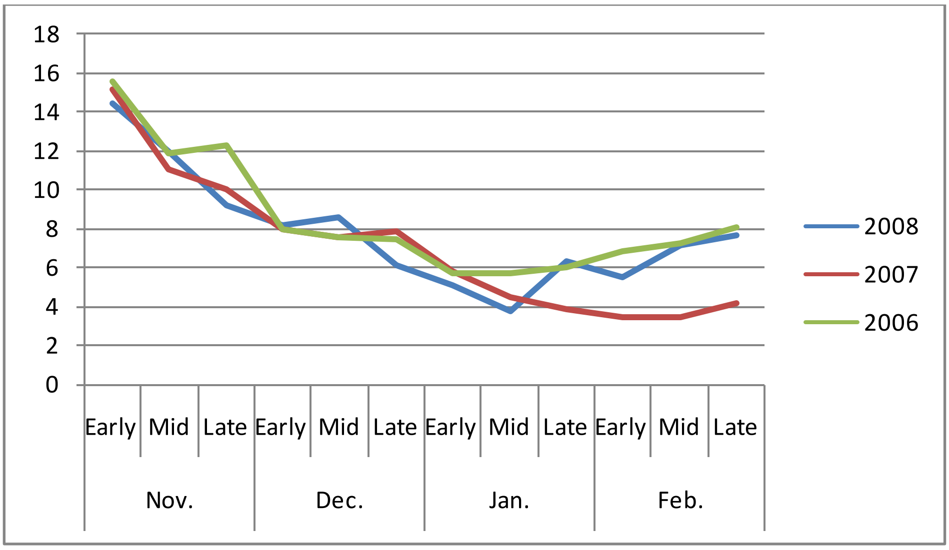

Figure 2. Changes in temperatures (Winter, Kyotanabe)[11]

Table 4. Energy consumption per unit(Kyotanabe)[6,7,8,9]

Year	2004	2005	2006	2007	2008	2009
Energy consumption per unit (L/m^2)	37.13	36.89	37.94	41.67	39.43	37.64

Table 5. A summary of the questionnaire survey results (2008, 2009)

	Campus	Male	Female	No response	Total
2008 Summer	Kyotanabe	526	563	0	1089
	Imadegawa	119	100	0	219
	Total	645	663	0	1308
2008 Winter	Kyotanabe	351	120	0	471
	Imadegawa	87	78	0	165
	Total	438	198	0	636
2009 Summer	Kyotanabe	1108	947	37	2092
	Imadegawa	428	462	21	911
	Total	1536	1409	58	3003
2009 Winter	Kyotanabe	772	701	82	1555
	Imadegawa	239	196	10	445
	Total	1011	897	92	2000

<Evaluation based on energy consumption per unit>

Table 4 shows changes in energy consumption per unit. According to the table, there was an increase in energy consumption until 2007, and it declined in 2008, which suggests the effects of the conservation efforts.

However, Doshisha University has not satisfied the criteria established in the Energy Conservation Act - an annual mean reduction of 1%, and a penalty will be imposed according to the government's policy if the university does not improve this situation. To address this issue, the university is required to continue reducing energy consumption by further promoting and improving energy conservation efforts. The following chapters discuss the possibilities of promoting and improving energy conservation efforts, which have produced positive results to some extent:

3. Evaluation based on Comfort Levels

3.1. Evaluation Methods

One of the energy conservation activities is the maintenance of temperatures at the same level in all classrooms, and comfort levels among students attending classes serve as an index for determining its validity. Therefore, questionnaire surveys involving students and the measurement of temperature and humidity was conducted to determine effective temperatures, and the sense of comfort among students was also assessed.

3.1.1. Questionnaire Survey

During the period of the energy saving activities, a multiple-choice survey involving students was conducted to examine their awareness of these activities and their necessity. Tables 5 and 6 show a summary of the questionnaire survey results based on the Doshisha Eco Project reports on their energy conservation activities. The survey methods varied depending on the period because of differences in the form of support provided by the university.

Following an explanation of the purpose of the survey, questionnaire forms were distributed to and completed by students during lectures, and were collected at the end of the lectures. Students were asked to choose among response options and describe their opinions.

Table 6. Classrooms in which measurements were conducted

	Area of the floor (m^2)
TC2-101	715.0
MK302	396.7
M21	648.5
R302	188.7

3.1.2. Measurement of Temperature and Humidity

Researchers measured the temperatures and humidity levels in classrooms during lectures. Following the distribution of the questionnaire forms, the readings of one to three thermometers and hygrometers installed in each classroom were recorded once every 15 minutes.

This temperature survey was conducted to confirm that the temperature in each classroom was actually set to 28°C (in the summer) or 20°C (in the winter) through air conditioner temperature control. The survey started in 2009 because a large number of students in different classrooms of the same room temperature felt differently during the survey period in 2008.

3.2. Survey Results between 2008 and 2009

3.2.1. Question Survey Results between 2008 and 2009

Students' responses to the following question were examined: "The temperature setting has been changed. Do you feel comfortable now?." Different response numbers were used depending on the time when the survey was conducted. In addition to the temperature survey described later, the question was asked to examine the effects of the temperature setting of 28°C (in the summer) and 20°C (in the winter) on students. Figures 3, 4, 5, and 6 show the results; approximately 50% of the respondents stated that the room temperature was appropriate. However, during all four survey periods, around 50% felt hot in the summer period and cold in the winter period, which suggests that the energy conservation efforts failed to create a comfortable environment for listening to lectures. The rate of students who felt comfortable in the summer period was approximately 10% lower than that in the winter period. Table 7 shows the responses to the question: "Can you tolerate this room temperature?" Response options were[1: Yes] and[2: No]. A total of 13.87% to 30.43% of students chose[2: No] depending on the classroom. These results suggest that improvements in the environment for listening to lectures are required. A larger number of students could not tolerate the room temperature setting in the summer season.

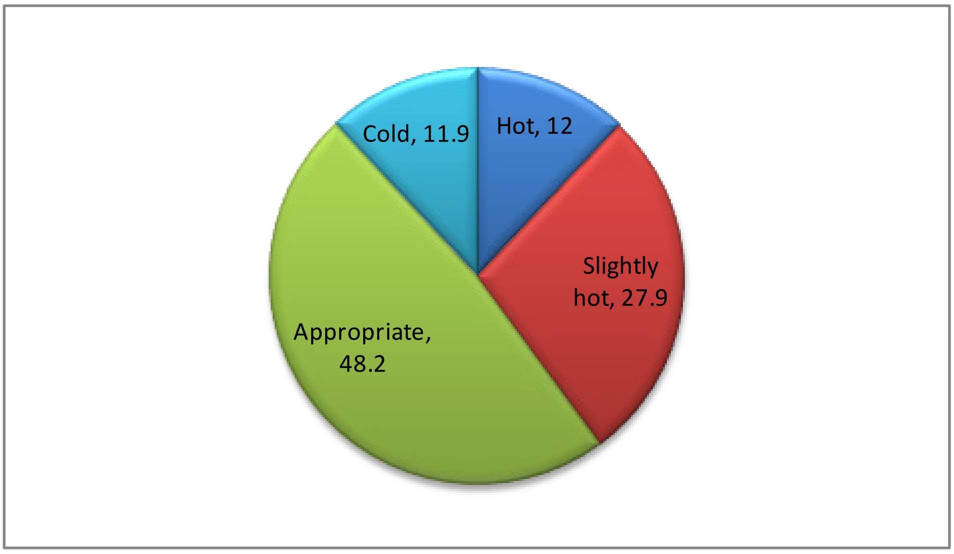

Figure 3. Responses to the question: "The temperature setting has been changed. Do you feel comfortable now?" (Summer of 2008)

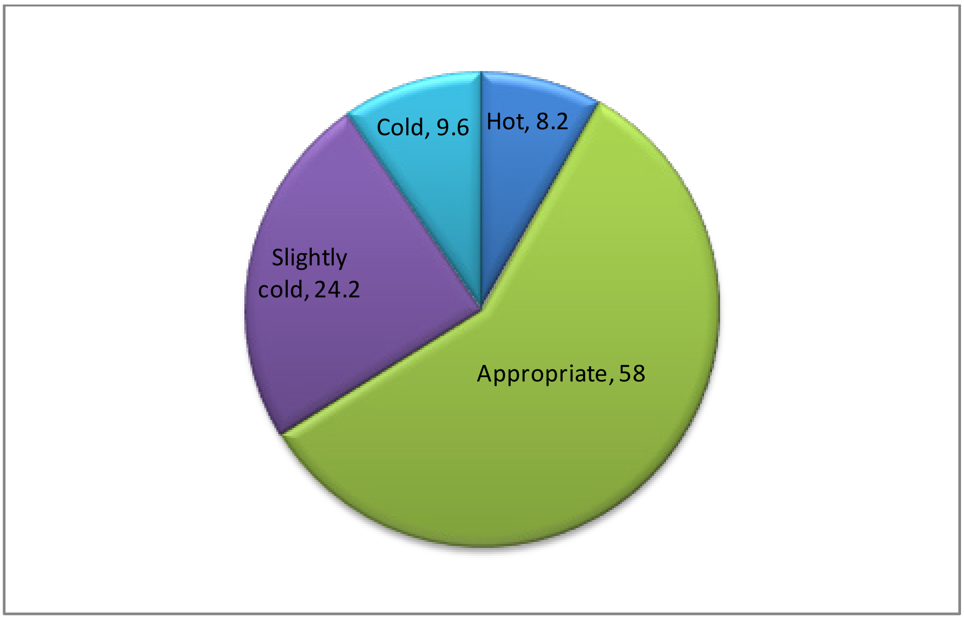

Figure 4. Responses to the question: "The temperature setting has been changed. Do you feel comfortable now?" (Winter of 2008)

Table 7. Responses to the question: "Can you tolerate this room temperature?" (2008 and 2009, total percentage of Kyotanabe and Imadegawa students)

		Yes (%)	No (%)
2008	Summer	69.57	30.43
	Winter	70.30	29.70
2009	Summer	71.72	22.04
	Winter	86.13	13.87

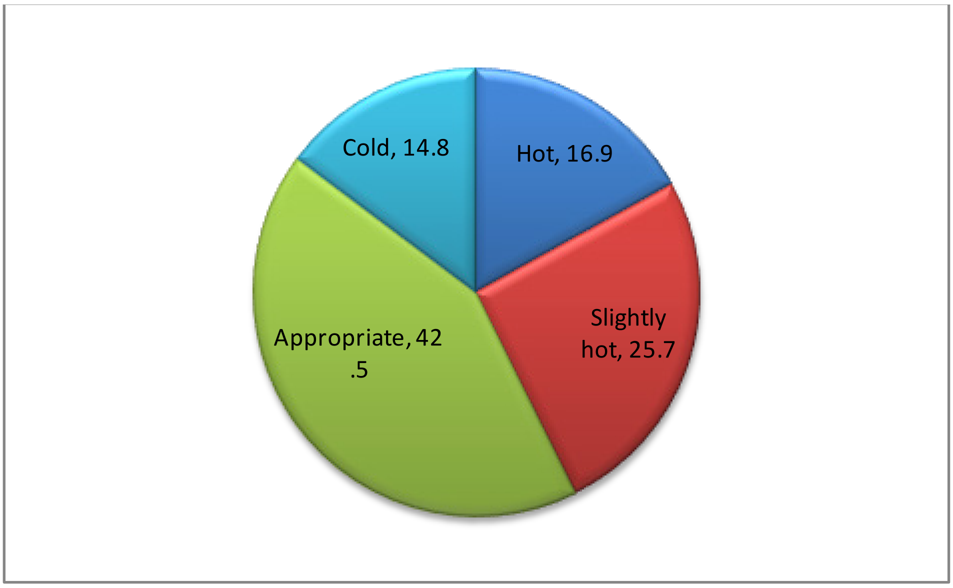

Figure 5. Responses to the question: "The temperature setting has been changed. Do you feel comfortable now?" (Summer of 2009)

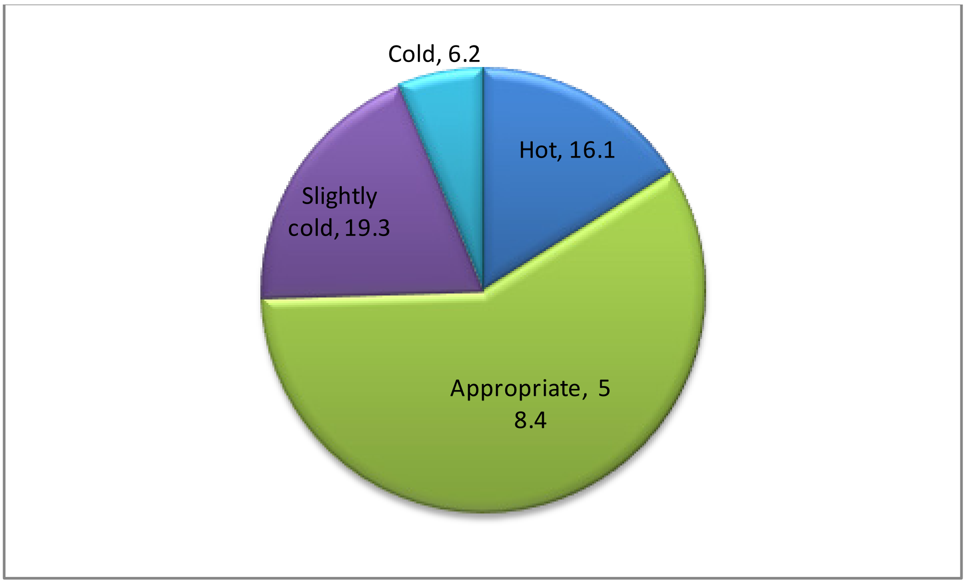

Figure 6. Responses to the question: "The temperature setting has been changed. Do you feel comfortable now?" (Winter of 2009)

<Differences in comfort levels between males and females>

Responses to the question: "The temperature setting has been changed. Do you feel comfortable now?", were examined to identify differences in comfort levels between male and female students (Table 8).

Table 8. Responses to the question: "The temperature setting has been changed. Do you feel comfortable now?" (2008 and 2009)

	2008 Summer		2008 Winter		2009 Summer		2009 Winter	
	Male	Female	Male	Female	Male	Female	Male	Female
Hot	16.07	7.96	10.41	3.09	23.36	7.50	18.73	13.30
Slightly hot	29.37	26.49			28.76	19.98		
Appropriate	48.07	48.39	65.16	41.75	39.21	39.04	60.39	54.90
Slightly cold			18.55	37.11			16.27	23.45
Cold	6.49	17.15	5.88	18.04	8.67	17.86	4.61	8.34

The study results revealed that a larger percentage of female students felt cold, whereas the rate of male students who felt hot was higher. There were few female students who stated that the room temperature was appropriate in the winter season. Male students had a lower tolerance for heat, while females were sensitive to the cold, which was presumably due to differences in their clothing. These results suggest that it may be necessary to change the temperature setting when classes are attended by a large number of female students.

3.2.2. Measurement of Temperature and Humidity in 2009

<Temperatures and humidity levels in classrooms>

Changes in the room temperature and humidity over time were examined in classrooms in which the set temperature was "28°C for the summer" and "20°C for the winter". Figures 7 and 8 show the results; the horizontal and vertical axes were the temperature and humidity. Figures 9 and 10 represent the mean temperatures and humidity levels per hour in Kyotanabe and Imadegawa Colleges during the summer season, and Figures 11 and 12 represent those in the winter season; changes in temperatures and humidity levels over time are shown in these charts.

During the period of energy conservation, the mean classroom temperature was 26.75°C in the summer season - lower than the set temperature of 28°C, and the mean room temperature in the winter season was 22.34°C - higher than the set temperature of 20°C.

On the other hand, there were significant differences in the humidity in the summer season even when the room temperature did not markedly change. The maximum difference in the humidity among classrooms was approximately 20%rh, and the mean difference was 8.86%rh. This was because only temperatures were controlled by the air conditioners. On the other hand, the mean difference in the humidity was only 3.83%rh in the winter season. The smaller difference in humidity levels suggests that classes in the university were less affected by energy conservation activities.

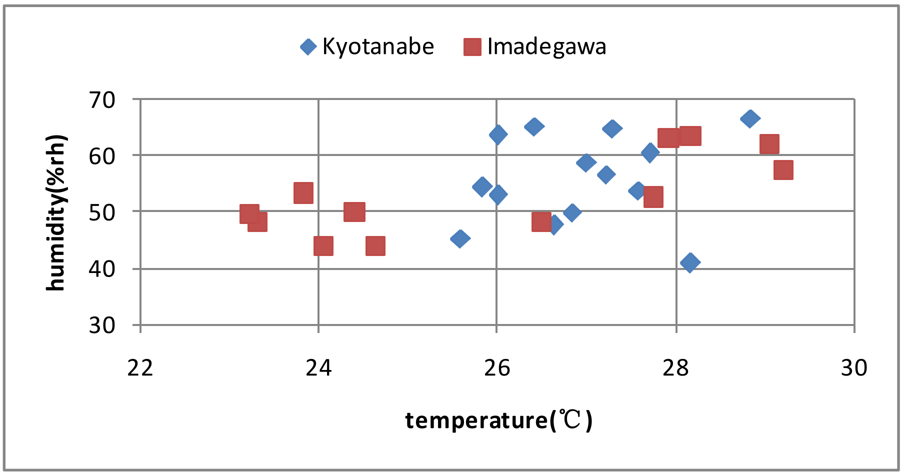

Figure 7. Temperatures and humidity levels in classrooms during the period of energy saving (summer of 2009, room temperature set at 28°C)

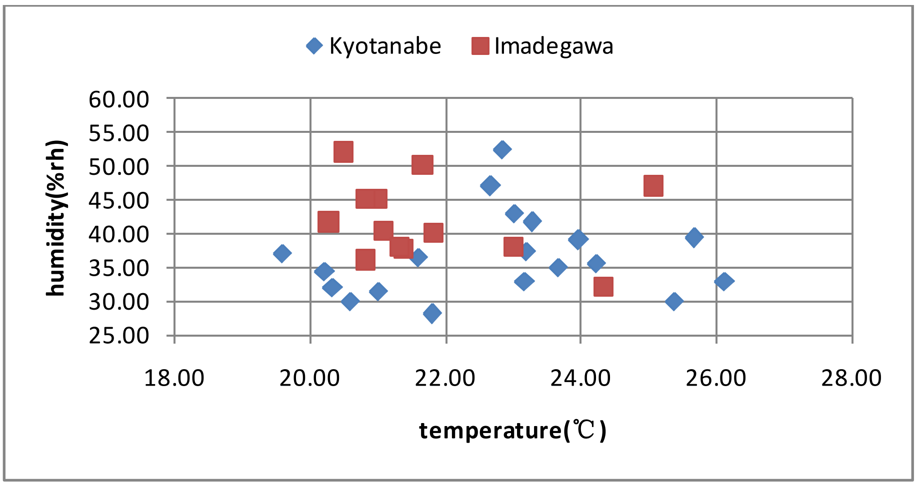

Figure 8. Temperatures and humidity levels in classrooms during the period of energy saving (winter of 2009, room temperature set at 20°C)

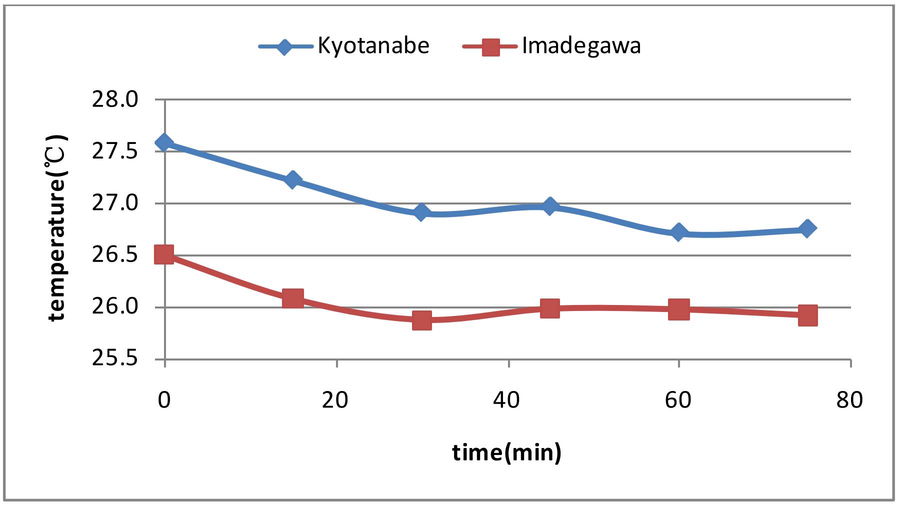

Figure 9. Changes in the classroom temperature (summer of 2009, every 15 minutes, temperature set at 28°C)

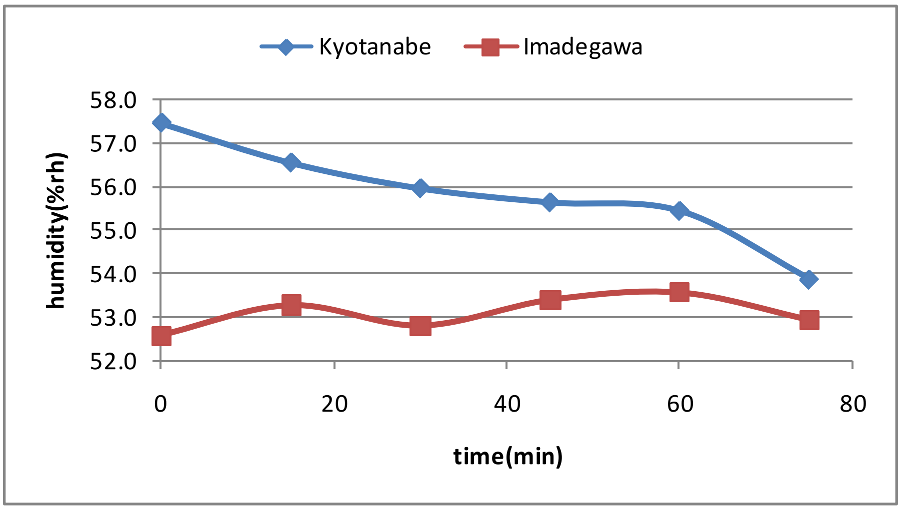

Figure 10. Changes in the classroom humidity (summer of 2009, every 15 minutes, temperature set at 28°C)

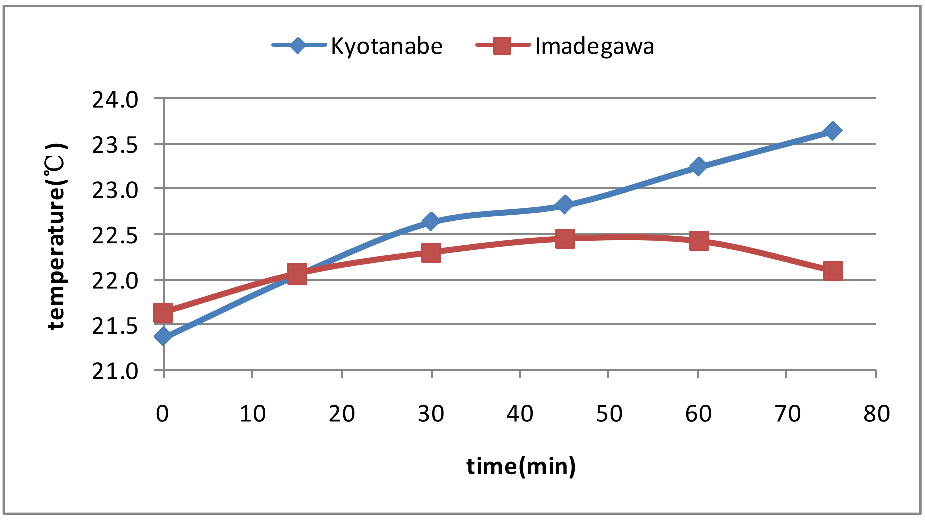

Figure 11. Changes in the classroom temperature (winter of 2009, every 15 minutes, temperature set at 20°C)

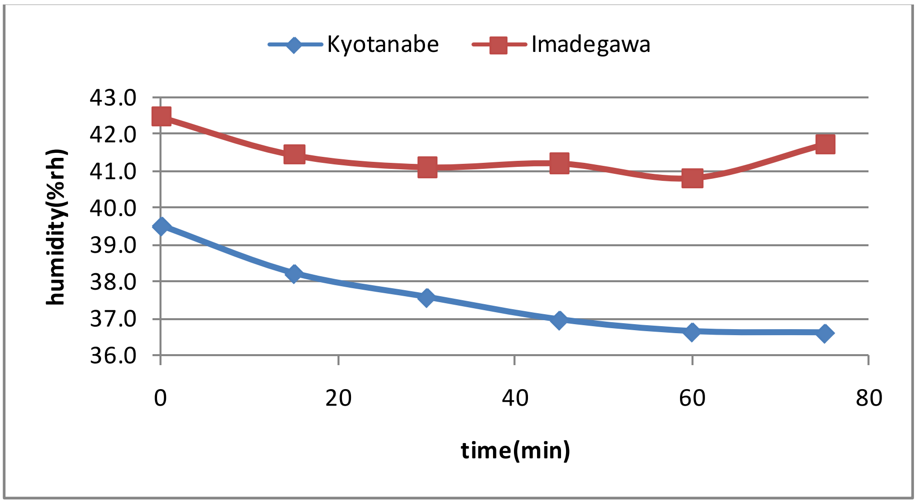

Figure 12. Changes in the classroom humidity (winter of 2009, every 15 minutes, temperature set at 20°C)

Furthermore, when using air conditioners, the outdoor temperature is not considered to be an important factor influencing the room temperature. Although the outdoor temperature was expected to affect the room temperature during the summer and winter because of a marked difference between outside and room air temperatures, the classroom temperature did not significantly differ from the set temperature and was not actually influenced by the outdoor air. However, this does not apply to the effective temperature sensed by individuals, and a marked difference between outside and room temperatures is considered to significantly influence the sense of comfort recognized by students at the beginning of a lecture, who have just entered the classroom from the outside.

<Comfortable temperatures and humidity>

According to a previously conducted survey, people feel comfortable when the combination of the temperature and humidity satisfies the conditions described in Table 9[12].

Table 9. Combinations of temperatures and humidity levels that create a comfortable environment (wind velocity: 0.3m/s)

	Temperature	Humidity
Summer	26～27℃	50～60%
Winter	20～22℃	40～60%

In the summer of 2009, only one of the 26 classrooms that had undergone the survey satisfied the criteria for comfortable temperatures and relative humidity. However, as described in the preceding paragraphs, approximately 50% of students felt comfortable. In the winter of 2009, five of the 36 classrooms satisfied the criteria, and around 60% felt comfortable.

The cause of the difference between the sense of comfort as perceived by students and the temperatures measured presents a serious problem in determining the optimum room temperature for energy conservation activities. The difference was presumably caused because "the room temperature was appropriate, although there were some students who did not feel comfortable", or because "either effective or measured temperatures cannot be trusted". If the cause is attributed to the former reason and the room temperature was actually close to the optimum set temperature, energy saving efforts need to be improved based on these results. If the cause is due to the latter reason, the evaluation method must be reviewed. Therefore, to determine the cause, the following paragraph focuses on effective temperatures as sensed by students.

<Effective temperatures>

An effective temperature in this study refers to the level of comfort sensed by people expressed as a temperature. An effective temperature is affected not only by the room temperature, but also by humidity, wind velocity, and sunlight. Missenard's formula is used to calculate the effective temperature based on the actual temperature and humidity (Formula 1)[13].

$$T_m = t - \frac{1}{2.3}(t-10)(0.8 - \frac{h}{100}) \qquad (1)$$

Tm = Effective temperature (°C) *t* = Temperature (°C) *h* = Relative humidity (%)

The present study discussed the effective temperature expressed by Formula 1 without taking into account the wind velocity and sunlight because temperatures and humidity levels were measured in large classrooms. Figures 13 and 14 show changes in effective temperatures calculated from the temperatures and humidity levels measured in the summer and winter of 2009. Effective temperatures were calculated using Formula 1, and the maximum and minimum effective temperatures that satisfied the conditions for a comfortable environment, stated in Table 9, were also plotted as Tm (max) and Tm (min), respectively, on the chart.

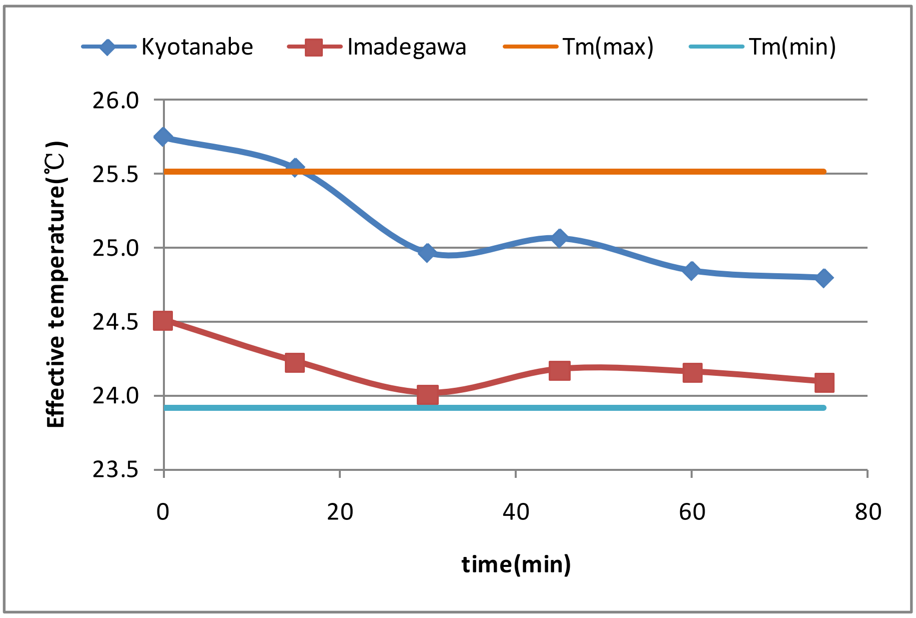

Figure 13. Changes in the effective temperature in classrooms (summer of 2009, every 15 minutes, temperature set at 28°C)

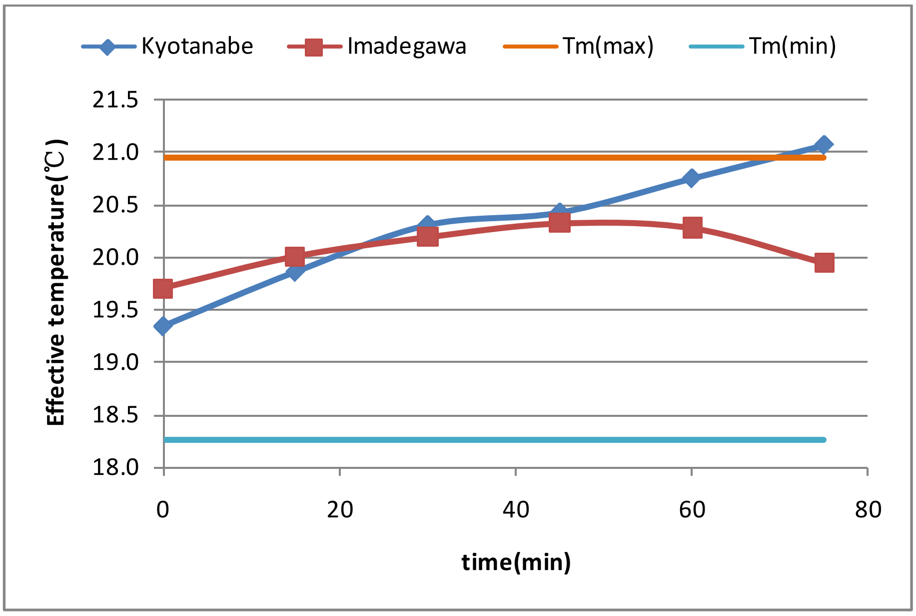

Figure 14. Changes in the effective temperature in classrooms (winter of 2009, every 15 minutes, temperature set at 20°C)

The combination of temperature and humidity during the majority of a lecture satisfied the requirements for a comfortable environment. When the room temperature is far outside the range of a comfortable environment expressed by the above-mentioned table of the combinations of temperatures and humidity levels, the room temperature will significantly differ from the effective temperature calculated by Missenard's formula. This suggests that although the current temperature settings of "28°C in the summer" and "20°C in the winter" did not provide a significantly uncomfortable environment, it was not an environment in which all students felt comfortable. However, when a classroom environment is neither significantly uncomfortab le nor sufficiently favorable, it is difficult to quantitatively determine the tolerance level.

3.2.3. Conclusions and Challenges Based on the 2008 and 2009 Survey Results

The following findings were produced by the energy conservation activities implemented during the four periods in each of 2008 and 2009:

- These activities produced energy conservation effects.
- Even when the room temperature was below the set temperature, approximately 50% of students felt uncomfortable and complained, particularly in the summer.
- Approximately 50% of students felt uncomfortable when they were in a classroom with a combination of temperature and humidity that was believed to create a comfortable

environment.

It seems that energy conservation effects were presumably produced at the sacrifice of comfort. However, the majority of students felt uncomfortable when they were in a classroom with a combination of the measured temperature and humidity level that did not provide an uncomfortable environment, or even created a comfortable environment.

3.3. Results of the Survey Conducted in the Summer of 2010

3.3.1. Revision of the Methods for the Energy Conservation Survey

The questionnaire survey and measurement of temperatures and humidity levels conducted in 2009 identified a problem in which the current activity, in which the temperature is set at 28°C in the summer and 20°C in the winter, produced energy saving effects at the cost of comfort.

Since energy conservation effects or environmental benefits should be compatible with comfort or sociality/economy, modifications were added to the question items in the summer of 2010 to examine whether or not comfort levels were reduced through energy saving efforts as well as its causes.

In 2009, the survey was conducted during a period of one week; questionnaire forms were distributed to students at the beginning of each lecture in four classrooms: TC2-101, MK302, M21, and R302, and temperatures and humidity levels were measured every 15 minutes. However, the survey identified some issues, including “There was no correlation between the measured temperatures and humidity and comfort levels” and “Temperatures and humidity levels were measured over a period of only one week during which there was little difference in the outdoor temperature”. The first problem may be attributed to the fact that, whereas room temperatures and humidity levels were measured over a specific period of time, the questionnaire survey was conducted only once. Regarding the second problem in which “the outdoor temperatures are considered to have had little influence on the air conditioner settings”, survey methods were changed to examine these points: “Questionnaire surveys were conducted twice (at the beginning and end of each lecture)” and “Temperatures and humidity levels were measured once a week over a period of several weeks”.

3.3.2. Survey Results in the Summer of 2010

<Changes in effective temperatures during lectures>

The question: “Q2: The temperature setting has been changed. Do you feel comfortable now?”, was asked at the beginning and end of lectures. Figure 15 shows the responses written by the students of each college. Response options to each question were[1: Cold],[2: Slightly cold],[3: Appropriate],[4: Slightly hot], and[5: Hot]. The number[0] represented no response.

Effective temperatures were lower at the beginning and end of lectures as expected, which was consistent with students’ attitudes. However, contrary to the assumption, the percentage of students who felt cold was higher. No significant increase or decrease was noted in the number of students who could tolerate the change in the room temperature. This suggests that the change in the comfortable level among students was attributed to decreases in effective temperatures.

<Temperature and humidity measurements>

Temperatures and humidity levels were measured in the same manner as in 2009. First, changes in temperatures and humidity levels over time were examined. Mean temperatures and humidity levels during lectures were plotted on a chart with the horizontal axis for the temperature and vertical axis for the humidity (Figure 17). Figures 18 and 19 show hourly changes in the mean room temperature and humidity in the two colleges; the horizontal and vertical axes represent the time and temperature or humidity, respectively. Figure 20 shows changes in the effective temperature, calculated from the temperatures and humidity levels measured in the summer of 2010. Effective temperatures were also calculated based on Table 9 (of comfortable temperature-humidity combinations) using Formula 1, and the maximum and minimum effective temperatures were represented as Tm (max) and (min), respectively. Effective temperatures were calculated using Formula 1, and the maximum and minimum effective temperatures that satisfied the conditions for a comfortable environment, stated in Table 9, were also expressed as Tm (max) and Tm (min), respectively, on the chart.

Figure 16 shows responses to the question: “Q3: Can you tolerate this room temperature?”, asked at the beginning and end of lectures. Response options to each question were[1: Yes] and[2: No]. The number[0] represented no response.

The combination of the temperature and humidity in two of the 42 classrooms satisfied the above-mentioned conditions for a comfortable environment - the percentage was consistent with the results of the survey conducted in the summer of 2009. However, the mean temperature declined to 25.5°C, more than 1°C lower than the previous year, and there was little change in the room temperature during lectures. The mean difference in the humidity was smaller - 4.78%rh. While the room temperature continued to decline over time in 2009, it rose in the middle of lectures and dropped to the same level as the start of lectures again in 2010. There was no difference in the effective temperature, although it was lower than in 2009. The mean effective temperature in Imadegawa College was lower than comfortable levels.

<Air conditioners and effective temperatures during the survey period>

Changes in the effective temperatures sensed by students (expressed in responses to Q2) during the one-month summer period were examined (Figures 20, 21, 22, 23, and 24). Classrooms were cooled from June 18. It was assumed that, as the outdoor temperature rose in July, or the middle of summer, a larger number of students in classrooms of 28°C would feel hot and uncomfortable.

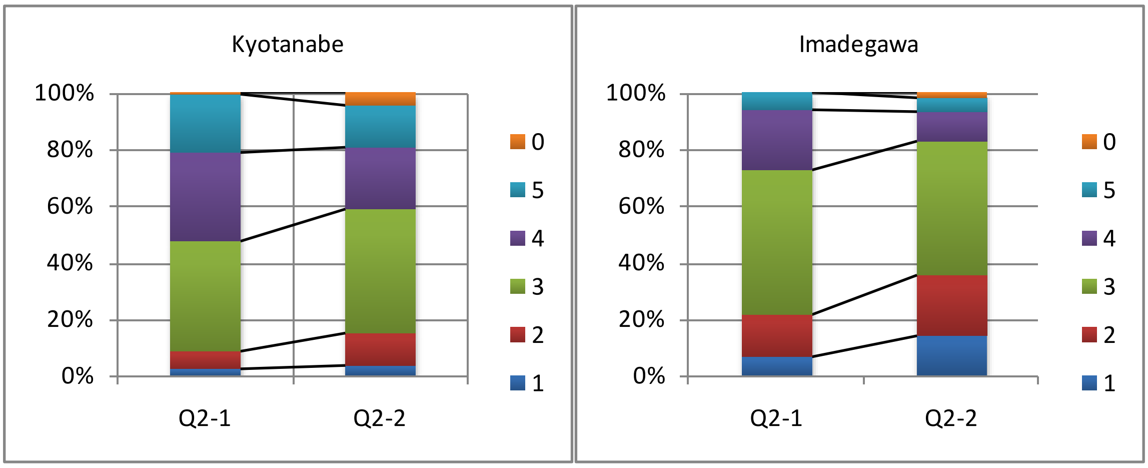

Figure 15. Responses to the question: "The temperature setting has been changed. Do you feel comfortable now?" (summer of 2010, Kyotanabe and Imadegawa)

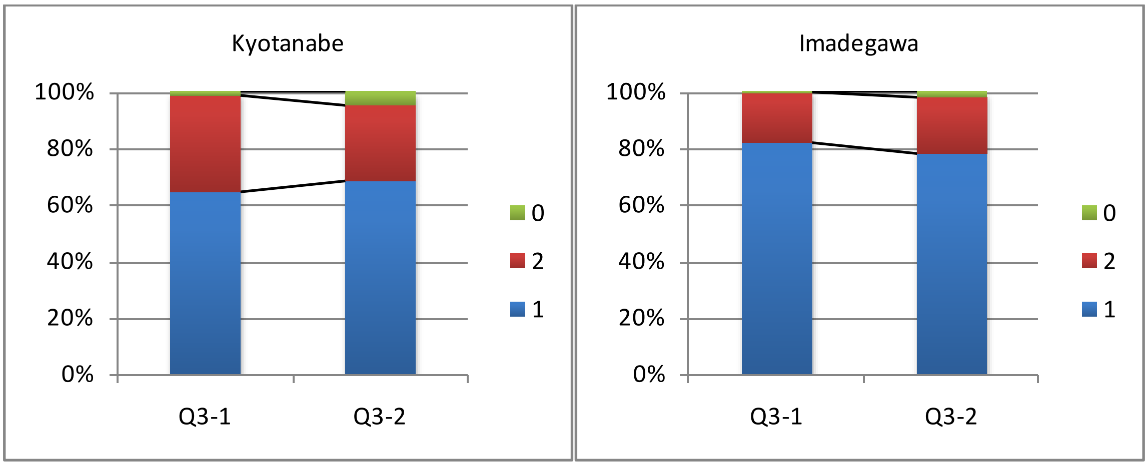

Figure 16. Responses to the question: "Can you tolerate this room temperature?" (summer of 2010, Kyotanabe and Imadegawa)

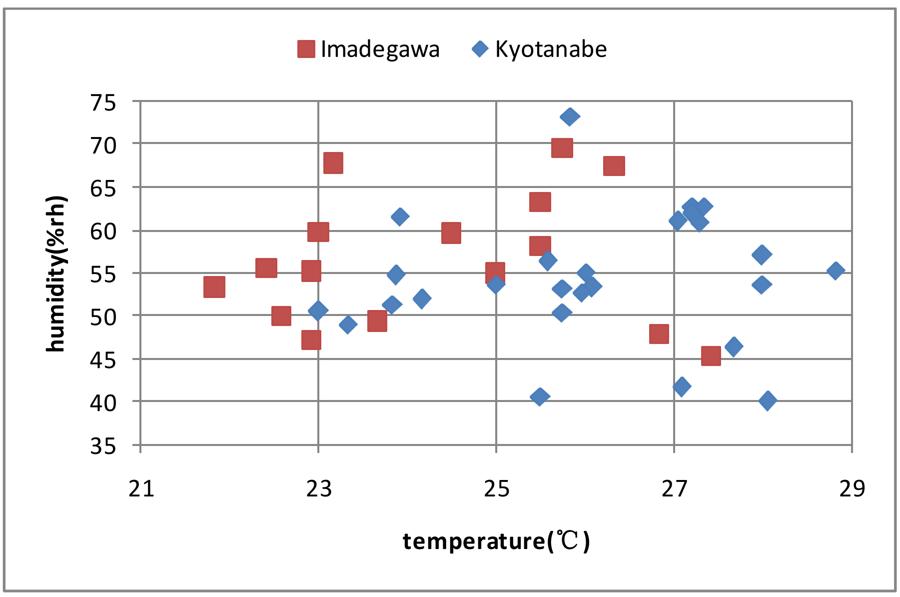

Figure 17. Temperatures and humidity levels in classrooms during the period of energy saving (summer of 2010, temperature set at 28°C)

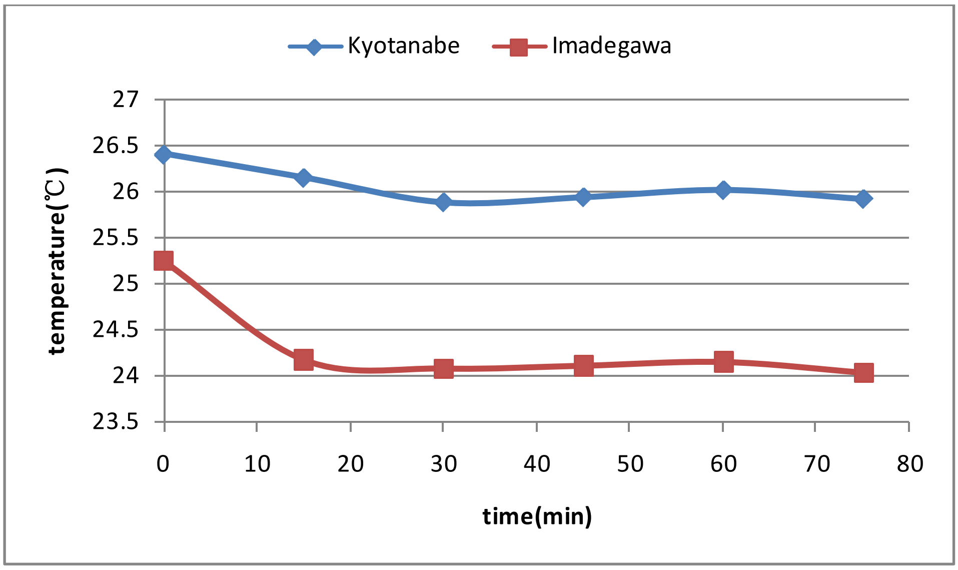

Figure 18. Changes in the classroom temperature (summer of 2010, every 15 minutes, temperature set at 28°C)

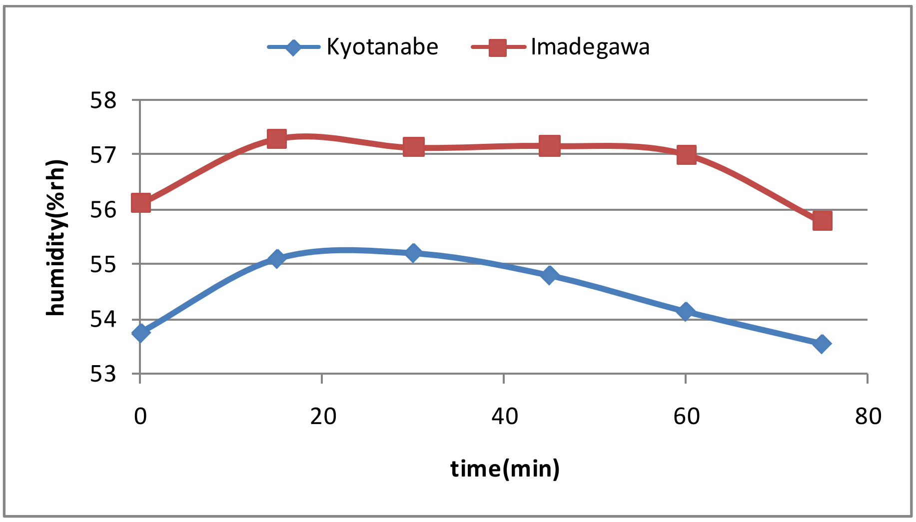

Figure 19. Changes in the classroom humidity (summer of 2010, every 15 minutes, temperature set at 28°C)

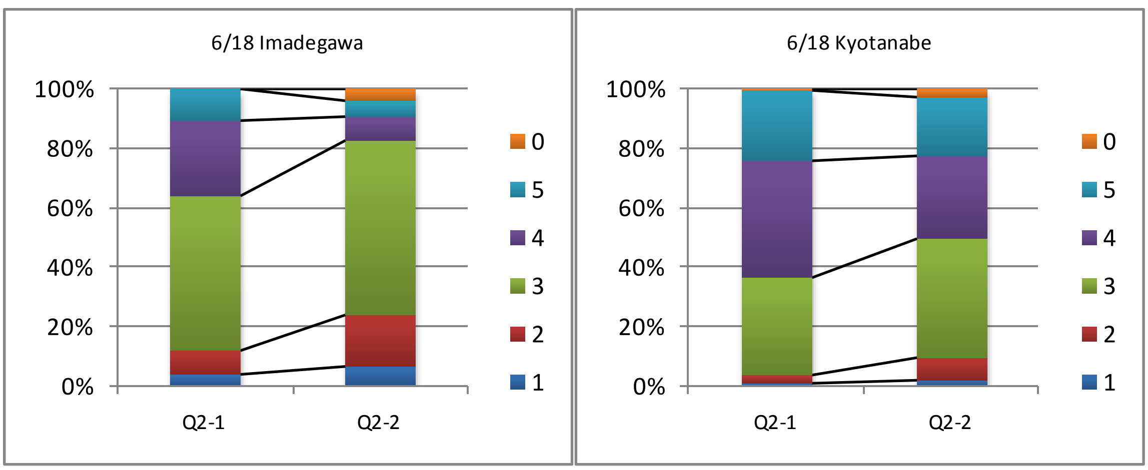

Figure 20. Responses to the question: The temperature setting has been changed. Do you feel comfortable now? (summer of 2010, 6/18, Kyotanabe and Imadegawa)

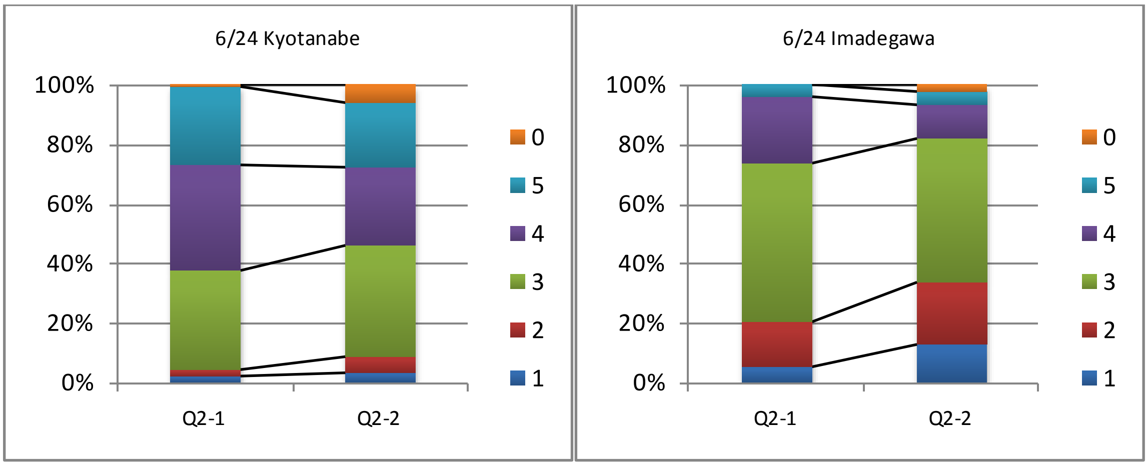

Figure 21. Responses to the question: The temperature setting has been changed. Do you feel comfortable now? (summer of 2010, 6/24, Kyotanabe and Imadegawa)

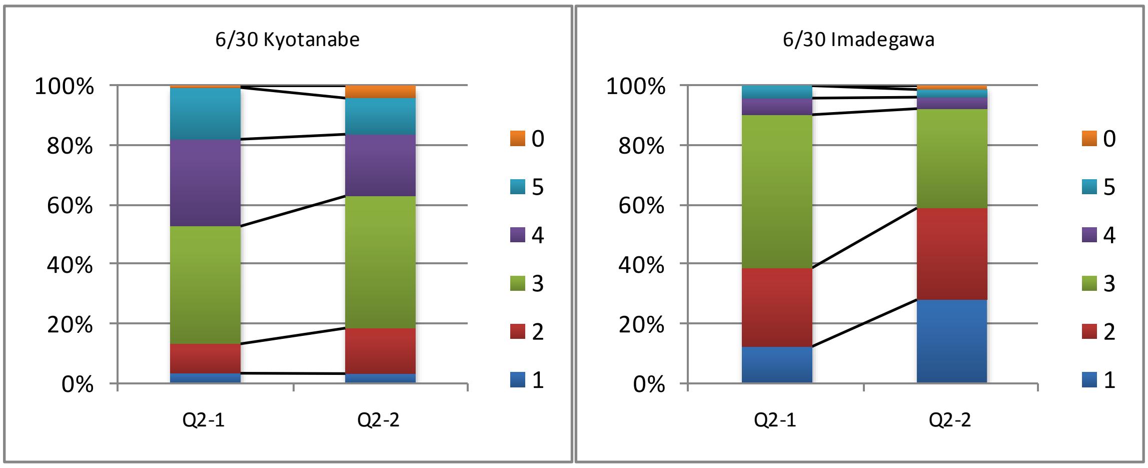

Figure 22. Responses to the question: The temperature setting has been changed. Do you feel comfortable now? (summer of 2010, 6/30, Kyotanabe and Imadegawa)

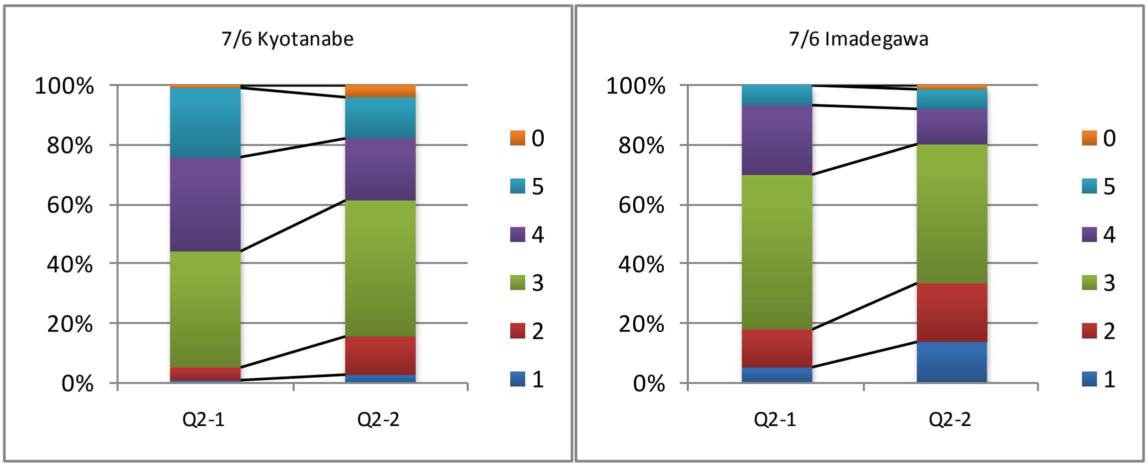

Figure 23. Responses to the question: The temperature setting has been changed. Do you feel comfortable now? (summer of 2010, 7/6, Kyotanabe and Imadegawa)

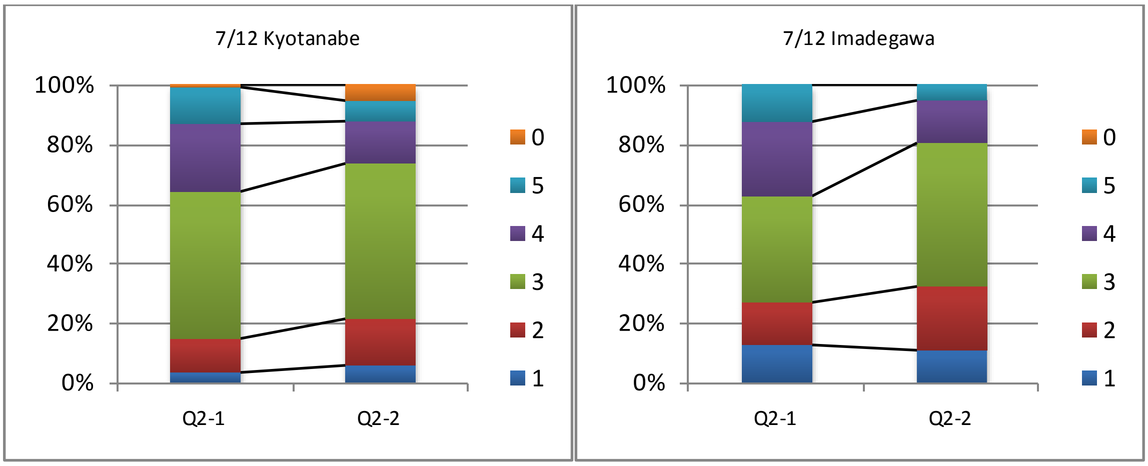

Figure 24. Responses to the question: The temperature setting has been changed. Do you feel comfortable now? (summer of 2010, 7/12, Kyotanabe and Imadegawa)

Contrary to the assumption of an increasingly larger number of people who would feel "hot" over time due to an increase in the outdoor temperature, fewer students felt hot at the start of lectures. This was because people feel comfortable when there is a large difference between outdoor and room temperatures. It stood to reason that a larger number of students felt comfortable at the start, rather than toward the end, of lectures in the second half of the survey period when the outdoor temperature was higher.

Still again, response options to each question through Figure 20-24 were[1: Cold],[2: Slightly cold],[3:Appropriat e],[4: Slightly hot], and[5: Hot]. The number[0] represented no response.

3.3.3. Discussion on the Results of the Survey in the Summer of 2010

<Correlations between sensible and actual temperatures>

Correlation analyses quantitatively evaluated the results of the questionnaire survey conducted in the summer of 2010 (Table 10).

Table 10. A summary of the questionnaire survey (summer of 2010) Campus

	Campus	Male	Female	No response	Total
Summer of 2010	Kyotanabe	1310	1506	98	2914
	Imadegawa	300	345	12	657
	Total	1610	1851	110	3571

A "correlation" refers to a relationship between two or more variables; when one of two variables increases, the other increases or decreases in proportion to the increased amount. A scatter diagram visually represents the relationship between two sets of data, whereas proportional relationships are expressed quantitatively. A "correlation analysis", a statistical analysis method, is used to analyze a proportional relationship between two sets of data, or the level of "linearity". A correlation efficient (Formula 2) expresses the level of correlation (if any) between two variables: x and y.

$$r = \frac{\sum_{k=1}^{n}(x_k - x_{avg})(y_k - y_{avg})}{\sqrt{\sum_{i=1}^{n}(x_i - x_{avg})}\sqrt{\sum_{i=1}^{n}(y_i - y_{avg})}} \tag{2}$$

In this case ($-1 \le r \le 1$), when r=1, Formula 2 represents a perfect positive correlation expressed by an upward slope, and, when r=-1, the formula represents a perfect negative correlation expressed by a downward slope. When $0.8 \le |r| <1$, the formula represents a "very strong correlation"; a "strong correlation" when $0.6 \le |r| \le 0.8$, a "moderate correlation" when $0.4 \le |r| \le 0.6$, a "weak correlation" when $0.2 \le |r| \le 0.4$, and "no correlation" when $0 \le |r| \le 0.2$ [14].

The correlation between changes in the temperatures sensed by students (x) and outdoor temperatures (y) was analyzed using correlation coefficients to quantitatively examine the influences of the outdoor temperature on room temperature. Specifically, the relationship between "changes in the temperature as sensed at the beginning and end of lectures" and the outdoor temperature was examined. The data required were "changes in the temperature as sensed at the beginning and end of lectures during the survey period" (Tables 11 and 12) and "outdoor temperatures" (Tables 13 and 14). Tables 11 and 12 show the effective temperatures at the start of lectures subtracted by those at the end. Therefore, the results are positive when the former is higher than the latter, and the results are negative when the former is lower than the latter. Tables 13 and 14 show outdoor temperatures on the days when the survey was conducted, as announced by the Japan Meteorological Agency, in the two colleges [11].

It was assumed that temperatures sensed by students attending lectures were affected the most by maximum outdoor temperatures, and correlations between maximum highs on the days when the survey was conducted in the two colleges and "changes in temperatures as sensed by students, asked in Questions 1 to 5". Tables 15 and 16 show the results obtained using Formula 1.

Table 11. Differences in the responses to the question: "The temperature setting has been changed. Do you feel comfortable now?"

	Q2 (1)	Q2 (2)	Q2 (3)	Q2 (4)	Q2 (5)
6/18	0.0108	0.0504	0.0840	-0.1065	-0.0337
6/24	0.0131	0.0359	0.0653	-0.0750	-0.0321
6/30	0.0002	0.0605	0.0674	-0.0752	-0.0470
7/6	0.0197	0.0911	0.0855	-0.0994	-0.0887
7/12	0.0271	0.0515	0.0583	-0.0778	-0.0499

Table 12. Differences in the responses to the question: "The temperature setting has been changed. Do you feel comfortable now?"

	Q2 (1)	Q2 (2)	Q2 (3)	Q2 (4)	Q2 (5)
6/18	0.0108	0.0504	0.0840	-0.1065	-0.0337
6/24	0.0131	0.0359	0.0653	-0.0750	-0.0321
6/30	0.0002	0.0605	0.0674	-0.0752	-0.0470
7/6	0.0197	0.0911	0.0855	-0.0994	-0.0887
7/12	0.0271	0.0515	0.0583	-0.0778	-0.0499

Table 13. Maximum, minimum, and mean temperatures (2010, Kyotanabe)

	Highest (℃)	Lowest (℃)	Average (℃)
6/18	25.5	21.0	22.7
6/24	31.3	18.2	23.8
6/30	32.2	23.5	27.2
7/6	32.8	23.6	27.1
7/12	29.2	23.4	26.7

Table 14. Maximum, minimum, and mean temperatures (2010, Imadegawa)

	Highest (℃)	Lowest (℃)	Average (℃)
6/18	25.9	21.1	23.0
6/24	31.8	17.3	24.2
6/30	32.8	23.3	27.2
7/6	31.9	24.5	26.9
7/12	29.7	24.2	26.7

Table 15. An analysis of the correlation between effective and room temperatures (summer of 2010, Kyotanabe)

	Q2 (1)	Q2 (2)	Q2 (3)	Q2 (4)	Q2 (5)
Maximum temperature	-0.0980	0.4480	-0.1678	0.4900	-0.5607
Mean temperature	0.1414	0.6270	-0.2457	0.3607	-0.6924

Table 16. An analysis of the correlation between effective and room temperatures (summer of 2010, Imadegawa)

	Q2 (1)	Q2 (2)	Q2 (3)	Q2 (4)	Q2 (5)
Maximum temperature	0.6723	-0.9225	-0.7799	0.8036	0.6835
Mean temperature	0.3255	-0.6827	-0.4282	0.7264	0.0924

When the above-mentioned index indicated "a strong or higher level of correlation" (or $0.4 =< |r|$) with the maximum or mean temperature, it was regarded as a correlation between the outdoor and effective temperature. For Kyotanabe College students, there was a positive correlation with "2: Slightly cold" and a negative correlation with "5: Hot", and there were no correlations with the other response options. For Imadegawa College, correlations were noted with response options other than "5: Hot"; there was an increase in the number of students who chose "1: Cold" and "4: Slightly hot", and a decrease for "2: Slightly cold" and "3: Comfortable". Qualitative evaluation results revealed that , during the hot season, a larger number of students felt cool around the end of lectures, and that a larger number of respondents who had felt comfortable at the beginning started to feel slightly cold toward the end of lectures because of a decrease in the effective temperature. These results were consistent with the measurement results. However, there were no significant differences in the effective temperature in Imadegawa College - a different environment, and a larger number of students felt increasingly hotter toward the end of lectures.

3.4. Conclusions Based on the Evaluation Results

Questionnaire surveys were conducted on energy conservation activities implemented until the summer of 2010, and the results identified the details of environmental problems associated with lecture classes:

- In the summer season, there were decreases in "comfort levels expressed as temperatures" during lectures due to changes in room temperatures and humidity levels.
- The environment for students to listen to lectures significantly varied depending on the college (campus), time, and classroom.
- The environment was affected by the outdoor air to some extent, although the level of this influence became increasingly lower.

These are the survey results. Considering the fact that comfort levels were low among students for the majority of the question items, as well as the discussion results relating to "comfort levels expressed as temperatures", it is very difficult to create an environment in which the temperatures in all classrooms are set to the same level. However, since facilities are obliged to reduce energy consumption per unit, as explained earlier, continued efforts are required to improve or maintain energy efficiency. According to the two results, it is necessary to maintain optimum temperature conditions in different classrooms, instead of the same room temperature throughout the university.

4. Conclusions

A multimodal evaluation on the achievements of the energy conservation activities implemented by Doshisha University, described in Chapters 2 and 3, identified a number of problems.

1) Environmental friendliness: Evaluation in terms of energy conservation effects

Although air conditioner temperature control throughout the university was effective, it did not fulfill the criteria established in the Energy Conservation Act.

2) Sociality: Evaluation in terms of comfort levels expressed as temperatures

Students did not feel comfortable during lectures, particularly in the summer season. However, since comfort levels expressed as temperatures vary depending on the gender, time of the measurement (start or end of lectures), season, and type of the classroom, differences due to these causes should be taken into account. In summary, it is necessary to shift to more flexible approaches, rather than a setting of the same temperature throughout the university, to develop favorable environmental models as a future challenge.

3) Continuity and expansion: Evaluation in terms of changes in attitudes

Few students had been involved in energy conservation activities on a continuing basis, and no marked changes were noted in the attitudes of those who had participated in such activities. As it is essential to promote larger-scale energy conservation activities to accomplish goals, efforts to increase the awareness of energy saving activities among students or promotion activities should be reviewed.

Energy conservation activities implemented by the university have several issues that need to be improved, as described in the preceding paragraphs. There was no change in students' attitudes toward "comfort levels expressed as temperatures", which is a particular problem. Although the fact that these activities improved energy conservation, which was the original goal, deserves attention, the goal itself could have been accomplished by any other means. It was not what only practical environmental approaches could have achieved.

As explained in the preceding chapters, practical environmental approaches have the advantage of promoting communication. Does reliance on technology provide complete solutions to environmental and energy resource problems? In my opinion, it will only postpone the addressing of problems, and does not provide solutions in a real sense; in fact, it will cause other problems. It is important to reform these systems to provide complete solutions, and such changes are made through economic and political activities. The behavior of the general public or consumers with sovereignty can cause changes in politics and economy, and people's behaviors are developed by their attitudes. Therefore, the communication required in practical environmental approaches that may influence politics and economy is very important. However, while some people involved in environmental activities supported them, others showed negative attitudes.

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[2] T. Okushi, N. Honda, and K. Mukai, Ontaiho to Shoeneho (Japanese), The Energy Conservation Center, Japan (2006) Chap. 3, 3.6.

[3] "Energy consumption per unit" in the present study, energy consumption divided by the value of an amount related to energy consumption, is defined as a unit used for the comparison of energy efficiency[15]. The simplest method for examining energy conservation efforts is the use of energy consumption as an index. However, energy consumption is significantly affected by the purpose and type of the plant. Therefore, the status of energy use and level of energy conservation in a facility can be determined by using the energy consumption per unit. However, although the Energy Conservation Act stipulates that facilities or plants should set a non-binding target of a mean annual year-on-year decrease in "energy consumption per unit", the law allows facility managers in charge of energy conservation to choose the divisor or unit; they are even also allowed to determine the number of years to calculate the mean annual decrease regarding the obligation to reduce energy consumption. Doshisha University has adopted the total area of the floor to divide the total amount of energy consumption[16]. This means that the energy consumption per area of the buildings of the university is calculated.

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[5] The Doshisha Eco Project is a student organization for energy conservation established under the Energy Saving Promotion Committee[17]. It was originally organized as a student environmental group designed to promote collaborative energy saving activities with teaching staff, as the committee considered that support provided by students was essential for these activities. The organization currently implements environmental education and practical environmental measures, including energy saving activities in the university, to help students with environmental learning as environmental projects to support their development. Reports on the summaries of these project activities implemented between 2008 and 2010 are available.

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