Study on Productivity in the Classroom (Part 3)  
Nationwide Questionnaire Survey on the Effects of IEQ on Learning Performance

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SUMMARY

Many research papers have been published on the potential effects of the quality of the indoor environment on productivity in classrooms and offices. This paper (Part 3) reports the result of nationwide field measurements based on subjective questionnaire surveys and objective test scores in a unified way.  
It investigated 83 branches of a college, which are located in regions spread throughout Japan. The total number of subjects was about 4000. Objective learning performance was evaluated according to scores in standardized quizzes to measure the level of understanding of lectures. In addition to the objective evaluation using quiz scores, a subjective evaluation of learning performance was carried out using a questionnaire as a self-assessment form.  
Percentage of dissatisfied of each schoolhouse did not have the correlation with quiz scores but had a significant correlation with a subjective evaluation of learning performance by a linear approximation (p<0.006).

INTRODUCTION

This series of studies evaluate the effects of changes in the air quality and thermal environments on student performance in the classroom. We have already reported the effect of indoor environmental quality on student performance based on field intervention surveys and laboratory experiments.  
This paper (Part 3) reports the result of nationwide field measurements based on subjective questionnaire surveys and objective test scores in a unified way. In this research, the relationship between the quality of the indoor environment and student performance in college are linked quantitatively through this nationwide questionnaire survey and previous laboratory experiments. In addition, human psychology regarded to effect it most when learning performance is measured was evaluated “motivation for learning” using a questionnaire as self-assessment form.

NATIONWIDE QUESTIONNAIRE SURVEY METHODS

Questionnaire surveys were conducted to evaluate the relationship between satisfaction level and learning performance at branches of Nikken Gakuin College – i.e. the college used for the intervention surveys in the previous paper (Part 1) [Murakami, et.al, 2006].  
Questionnaire surveys were carried out three times in total: in February 19, 2006 (winter) April 2, 2006 (spring), and June 11, 2006 (summer) at branches of the 83 Nikken Gakuin
College scattered over all regions of Japan. Two evaluations methods – an objective evaluation based on quiz score and a subjective evaluation based on a questionnaire on psychological factors – were used, and consistency was evaluated as well. In addition, human psychology regarded to effect it most when learning performance is measured was evaluated “motivation for learning” using a questionnaire as self-assessment form.

The lecture started at 9:00am. After the 180-minutes lecture ended (12 noon), the subjects took a 30-minute quiz, and then filled out the self-assessment form (questionnaire). Three five-minute breaks were provided during the 180-minute lecture.

The trial subjects were students taking a course for the qualifying examination for first-class architects. Those students were all highly motivated because nearly all of them were to take a qualifying examination scheduled for July. The total number of subjects was about 4000, most of whom were employed and in their twenties to forties. Since the students need to attend all of the lectures based on the curriculum provided by the college, the subject groups in individual measurement cases were almost the same.

Evaluation of learning performance

1) Evaluation of Objective Learning Performance

Objective learning performance was evaluated according to scores in standardizes quizzes to measure the level of understanding of the lectures. The purpose of the lectures was to prepare students to take the qualifying examination for first-class certified architects. Each standardized quiz consisted of 20 questions, each of which was answered by choosing one of five options. Table 1 shows questions in a typical standardized quiz. To compare scores in quizzes for different lecture content, an adjustment was made to the scores based on data on the average scores in the examinations conducted by Nikken Gakuin College in fiscal 2006, and the difficulty levels of all examinations were standardized.

Table 1. Questions in Standardized Quizzes for the Objective Evaluation (in the field of architectural planning)

<table>
<thead>
<tr>
<th>Question 10: Which of the following descriptions of different wiring methods used in office construction is the most incorrect?</th>
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<tr>
<td>(1) In the free-access floor wiring method a double floor is constructed, and the method uses the space between floors as the wiring space; this has the effect of reducing the design load on the floor.</td>
</tr>
<tr>
<td>(2) The floor on the standard floor was made to the free-access floor of 6cm in height, and to correspond to the change in the layout of the office, considered in the office building.</td>
</tr>
<tr>
<td>(3) In the under-the-carpet wiring method a thin cable is laid directly on the floor level, and a special floor finish is needed. However, it is possible to correspond to the change easily.</td>
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<td>(4) It wires a necessary place, and the bus baton wiring method is large the maximum, permissible current, and in the method to accommodate and to protect the conductor in this, is suitable for a mass power supply.</td>
</tr>
<tr>
<td>(5) In general, the conductors used in the bus baton wiring method are made of copper or aluminum.</td>
</tr>
</tbody>
</table>

2) Evaluation of Subjective Learning Performance

In addition to the objective evaluation using quiz scores, a subjective evaluation of learning performance was carried out using a questionnaire as a self-assessment form. Table 2 shows the self-assessment form. Subjective learning performance is evaluated with Questions 4-(1) and 4-(2) shown in Table 2. The filing return made it answer by the answer sheet exam. Since a choice prepared only to ten pieces, the choice was set up based on the reply obtained by the previous paper (Part 1).
Table 2. Self-Assessment Form for the Subjective Evaluation

**Question 1; Yourself**
(1) Gender? 1.) Male  2.) Female
(2) Age?  1.) 10’s  2.) 20’s  3.) 30’s  4.) 40’s  5.) 50’s  6.) 60’s

**Question 2; Thermal Environment (Heat and Cold)**
(1) How does the temperature feel?
   1.) Cold  2.) Slightly Cold  3.) Cool  4.) Moderate  5.) Warm  6.) Slightly Hot  7.) Hot
(2) Are you satisfied with the current thermal environment?
   1.) Dissatisfied  2.) Slightly Dissatisfied  3.) Neutral  4.) Slightly Satisfied  5.) Satisfied

**Question 3; Air Environment (Contamination and odor)**
(1) Are you satisfied with the current air environment?
   1.) Dissatisfied  2.) Slightly Dissatisfied  3.) Neutral  4.) Slightly Satisfied  5.) Satisfied

**Question 4; Understanding level of lecture contents**
(1) Please convert the effect and/or the frequency of effect of the indoor environment in the classroom on your understanding of today’s lecture contents into lost time.
   1.) 0 min  2.) 3 min  3.) 5 min  4.) 10 min  5.) 15 min
   6.) 20 min  7.) 25 min  8.) 30 min  9.) 40 min  10.) More than 50 min
(2) How is the understanding level of the content of the lecture thought to improve if the factor of the indoor environment improves the understanding level of today's content of the lecture as 100%?
   1.) 0%  2.) 5%  3.) 10%  4.) 15%  5.) 20%
   6.) 25%  7.) 30%  8.) 40%  9.) 50%  10.) Over 60%

**Question 5; Motivation for Learning (Motivation to absorb content of lecture)**
(1) After entering your classroom, how high was your motivation for learning (Motivation to absorb content of lecture)?
   1.) 0 -10  2.) 10-20  3.) 20-30  4.) 30-40  5.) 40-50
   6.) 50-60  7.) 60-70  8.) 70-80  9.) 80-90  10.) 90-100

**Evaluation of motivation for learning**
In this research, motivation for learning is defined as “motivation to absorb the content of the lecture.” The investigation about motivation for learning tries evaluation of the motivation by which evaluation quantitative until now was not made almost, though it is a very important parameter in productivity research. Motivation to learn during the lecture was assessed using a questionnaire as a self-assessment form, too. Motivation for learning during lecture is evaluated Question 5 shown in Table 2.

The significance level was set at 5% and a corresponding t-test was used to compare the quiz results with varying environmental conditions. The Wilcoxon matched-pairs signed rank test was used as a corresponding rank scale in comparing the results of the self-assessment with varying environmental conditions.

**RESULTS / LEARNING PERFORMANCE**

**Between learning performance and the percentage dissatisfied with the air environment**
Figure 1 shows the relationship between the learning performance and the percentage dissatisfied with the air environment. It classified according to the unit 5% after calculating the rate of dissatisfied of air environment for every school building. Furthermore, the average value was calculated. The size of the plot in a figure expresses the number of school buildings in the point. The number of school buildings is shown during the plot. That is, the average value of the learning performance of the school building shown in the number under plot is expressed.
Figure 1a) shows the relationship between the results of the object evaluation (quiz score) and percentage dissatisfied with the air environment. Although there was a tendency for the quiz scores to improve as the percentage dissatisfaction decreased, there was no significant correlation between the two.

Figure 1b) shows the relationship between the results of the self-assessment of time lost due to the indoor environment and the percentage dissatisfied with the air environment. Time lost due to the indoor environment is based on the response to Question 4-(1). A linear relationship was observed between the subjective evaluation of time lost and the percentage dissatisfied with the air environment ($R^2=0.76$, $p<0.003$). In addition, the notation is omitting because the items of the number of school buildings are the same as that of the result with objective evaluation in figure 1a).

Figure 1c) shows the relationship between the results of the self-assessment “predicted rate of improvement in learning performance with an improvement in the environment” and the percentage dissatisfied with the air environment. The subjects were requested to report the learning performance improvement rates that they expected if the indoor environment was improved. Predicted rate of improvement in performance is based on the response to Question 4-(2). A linear relationship was observed between the subjective evaluation of the predicted rate of improvement in performance and the percentage dissatisfied with the air environment ($R^2=0.68$, $p<0.006$).

In addition, it got the same result the relationship between the results of thermal environment and learning performance.

**Between objective evaluation and age**

Figure 2 shows the relationship between the quiz scores and age. A linear relationship was observed between quiz scores and age ($R^2 = 0.89$, $p<0.06$ (n.s.: no significant)). It is thought that it was generated by accumulating experience, whenever it passes through age for preparation of the qualifying examination carried out every year. It was a result with the same said of April and June. In productivity research, in case working and study performance are measured, there is the necessity that experience must be taken into consideration.
RESULTS / MOTIVATION TO LEARN

Distribution and classification of motivation to learn
Figure 3 shows the distribution of the motivation to learn during lectures in February. 70.3% of 2601 subjects among 3701 subjects reported themselves with 70% or more. It turns out that motivation for learning is kept high towards a qualifying examination. It was a result with the same said of April and June.

Then, the subjects were put into two groups: a higher motivation group (=Md(H)) and a lower motivation group (=Md(L)) to analyze the motivation during lectures on learning performance. Subjects in the higher motivation group were defined as those with 70% or more in the self-assessment.

Evaluation of learning performance by motivation group
Figure 4 shows the results for objective learning performance by the motivation group. The quiz scores brought a significant high of 4.5 points (p<1.1×10^-6) in February, 6.3 points (p<6.5×10^-14) in April, and 2.6 points (p<5.9×10^-5) in June by the Md(H) group. It became clear that the motivation to learn during the lectures significantly influencing the quiz scores, and the importance of evaluating the motivation to learn was shown. To measure the learning performance more exactly, it is thought necessary to incorporate motivation to learn as an evaluation axis.
DISCUSSION / DETAILED EXAMINATION OF THE LEARNING PERFORMANCE

Season
Figure 5 shows the relationship between the quiz scores and the percentage dissatisfied for air environments in every season. There was no significant correlation between the two in which season.

Next, Figure 6 shows the result of having excepted the school building whose rate of a dissatisfied of air environment was 30% or more. A fairly strong linear relationship was observed between the quiz scores and the percentage dissatisfied with the air environment, with $R^2=0.46$ in February, 0.47 in April, and 0.20 in June. In June, although the percentage dissatisfied with the air environment is high, a tendency with the sufficient quiz score can be observed. It is possible that students are carrying out the report by the side of nearby dissatisfaction more till because they become sensitive to environment then when the qualifying examination has approached. Moreover, even if dissatisfied, a possibility of doing themselves best can be considered.

Figure 7 shows the relationship between the time lost due to the indoor environment and the percentage dissatisfied with the air environment in every season. A linear relationship was observed between time lost and percentage dissatisfied with the air environment, with $R^2=0.29$ in February, 0.76 ($p<0.003$) in April, and 0.93 ($p<0.0001$) in June. The correlation becomes stronger as the qualifying examination approaches. It was a result with the same said of predicted rate of improvement in learning performance with an improvement in the environment.

From the above result, it is possible that relation is the period to a target, and the objective and subjective evaluation.
Figure 7 Subject Evaluation vs. Percentage Dissatisfied with the Air Environment by Season

Area
Figure 8 shows the relationship between the quiz scores and percentage dissatisfied with the air environment in every area for April. As candidates for the survey, Hokkaido and Tohoku were chosen as cold climates with 13 branches, Kanto as a moderate climate with 25 branches, and Kyushu as a hot climate with 11 branches. No relationship was observed between quiz scores and percentage dissatisfied with the air environment in cold and moderate climates. A linear relationship was observed with a significant correlation between the quiz scores and dissatisfaction in the hot climate ($R^2=0.42$, $p<0.03$). It was a result with the same said of February and June.

In addition, it got the same result the relationship between the results of thermal environment and learning performance.

**CONCLUSIONS**

(1) Objective learning performance improved with a decrease in the percentage dissatisfied with the air environment.

(2) Subjective learning performance improved significantly with a decrease in the percentage dissatisfied with the air environment.

(3) Objective learning performance improved with age.

(4) Objective learning performance in the high motivation group was significantly better. To measure the learning performance more exactly, it is thought necessary to incorporate motivation to learn as an evaluation axis.

(5) It is possible that relation is the period to a target, and the objective and subjective evaluation.
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