An Experimental Study to Determine Proper Lighting Conditions in Powder Rooms

Hyun-Ji Kim* · Jang-Hyeon Lim · Hoon Kim**

Abstract

In this study, a mock powder room was installed with variable LED lighting environments in order to conduct the experiments. The experimental conditions include luminaire type, illuminance ratio, vertical illuminance and color temperatures. The evaluation methods used were the Semantic Differential Method and a subjective evaluation on activities through observation.

The SD evaluation result factor analysis categorizes ideas into three factors: brightness, emotion, and glare. The vertical bracket or the combined luminaire (luminous panel+ Vertical bracket) has better brightness than luminous panel. A vertical illuminance of 500lx is not significantly difference as compared to 600lx, allowing 500lx to be considered standard. The emotional atmosphere is evaluated as being better at lower color temperature. The luminous panel is the best for reducing glare while the vertical bracket is the worst. The best conditions differ according to the illuminance ratio of the luminous panel and vertical bracket.

In the subjective evaluation (satisfaction with lighting environment, suitability to activity) the combined luminaire and 4000K received the best evaluation.

Key Words : Powder Room, Luminaire Type, Illuminance Ratio, Vertical Illuminance, Color Temperatures

1. Introduction

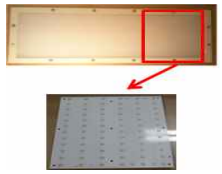Powder rooms are used for visually sensitive activities such as make-up, hair styling, accessorizing and on the like. These spaces are typically equipped with a mirror. Therefore, lighting installation method, vertical illuminance, color temperature and other related conditions are highly crucial. However, most powder rooms in Korea are installed with uniform lighting without considering the activities that are performed within the space. Additionally, there is almost no research on this topic. The study aims to determine the proper lighting environment conditions for powder rooms including luminaire type, vertical illuminance and color temperature.

 * Main author : Research Professor, Smart Lighting
    Research Center, Kangwon National
    University
** Corresponding author : Professor, Department of
    Electrical and Electronics Engineering,
    Kangwon National University
 Tel : +82-33-250-7320, Fax : +82-33-250-7321
 E-mail : kim9556@kangwon.ac.kr
 Date of submit : 2013. 10. 25
 First assessment : 2013. 10. 31
 Completion of assessment : 2013. 11. 16

2. Methods

2.1 Laboratory

The total area of the laboratory was 6,400×5,800×2,200mm and the powder-room was constructed at the size of 1,700×1,700×2,100mm. The vanity was installed 750mm above the floor at the wall across the entrance and a mirror (1200×1400mm) was installed above this vanity. Various cosmetics and a comb were put on the vanity top to create the atmosphere of a powder room. The entire laboratory apart from the powder room used minimal artificial lights, excluding natural lights, for the waiting space and the researcher performing the experiment.

Table 1. The lighting apparatus

	Luminous Panel (diffuse type)	Vertical Bracket (diffuse type)
size(mm)	970 × 380	50 × 950
electric power (W)	60	42
CRI	83	83
photo		

Picture 1. Laboratory

The lighting apparatus of the laboratory are shown in the Table 1 and Picture 1. The luminous panel was installed at the center of the ceiling above the vanity desk. The vertical brackets were each installed at both sides of the mirror.

2.2 Experimental Conditions

The experiment conditions include luminaire type, vertical illuminance, and color temperature, and thus generated a total of 27 condition combinations.

The combined luminaire is based on a ratio. The 1:1 ratio is 250lx for each source and has a total of 500lx. The following ratios all are 500lx, too. The 1:3 ratio is 375lx for the luminous panel and 125lx for the vertical bracket. The 1:3 ratio is 125lx for the luminous panel and 375lx for the vertical bracket.

Table 2. Experimental conditions

Luminaire Type		Vertical Illuminance(lx)			Color Temperature (K)		
Luminous Panel	Vertical Bracket	400	500	600	3000	4000	5000
Combined Luminaire		1:1	3:1	1:3			

2.3 Subjects

Table 3. Subjects

Age (average)	21.4 year old
Average eyesight (left/right)	0.9/0.9
School	K University Art Major female students

In this study, the number of subjects was less important than having reliable subjects. Juniors and seniors majoring in art design who are sensitive to colors and sensations were tested in the study in

order to obtain reliable results. Only female students participated in the experiment in order to eliminate gender bias. Twenty students were the subjects of this study.

2.4 Experiment Procedure

The experiment was conducted from May 23rd to 28th, 2013 and the session was composed of participant training, a preliminary experiment and the actual experiment.

The same conditions that were presented at first were also presented at the end to ensure data accuracy and to verify subject reliability. Evaluation conditions were presented randomly so as not to be influenced by the precious evaluation.

The evaluation methods were two types: the SD Method and Subjective Evaluation. Before conducting the SD evaluation, the subjects were asked to "tell the overall images of the powder room, intuitively" and check the evaluation sheet immediately after exiting the powder room area.

In the subjective evaluation, participants conduct the given action in the laboratory and answer the evaluation sheet. That is, the participants observe lipstick color or shirt color and answer the evaluation sheet questions.

3. Results

3.1 SD Evaluation Analysis

3.1.1 Comparison by Factor

The reliability analysis shows a relatively high Cronbach's Alpha of .886 and the factor analysis categorizes ideas into three factors (Table 4).
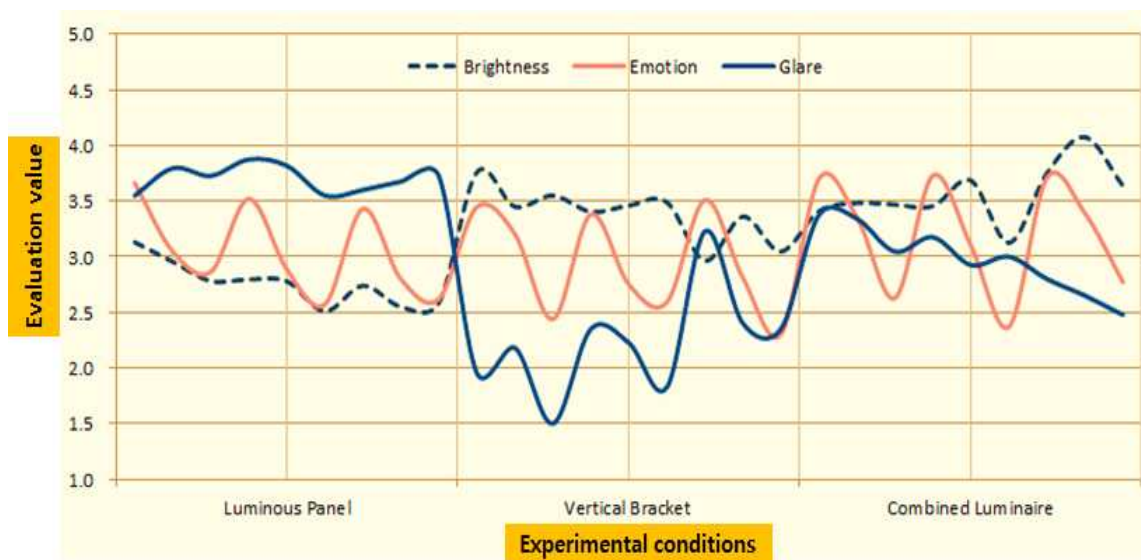
(※) Notice for graph of evaluation values
Not included in the graph are additional variables for the independent axis. The variables are not shown for convenience.
The variables include vertical illuminance and color temperature. Vertical illuminance shows no trend as well as color temperature. There is a trend for luminaire type.

Fig. 1. Comparison of evaluation value by factor

Table 4. Factor analysis

Factor	Evaluation items	Factor loading			Community	Factor name
		I	II	III		
I	clear-dim	0.812	0.122	0.108	0.686	Brightness
	clear	0.790	0.02	0.147	0.646	
	unclear	0.775	0.074	0.070	0.611	
	pleasant-unpleasant	0.742	0.424	0.157	0.755	
	satisfying-unsatisfying	0.738	0.393	0.026	0.700	
	pretty	0.718	0.436	0.227	0.757	
	joyful-gloomy	0.707	0.129	0.484	0.751	
	bright-dark	0.685	0.109	0.187	0.516	
	uniform-non-uniform	0.674	0.473	0.197	0.718	
	like-dislike	0.616	0.585	0.094	0.731	
	mirth-mirthless					
II	warm-cool	0.093	0.881	0.021	0.784	Emotion
	look is good - look is pale	0.464	0.713	0.043	0.726	
	natural-unnatural	0.137	0.634	0.461	0.633	
	comfortable-uncomfortable	0.262	0.560	0.525	0.658	
	similar to natural light	0.099	0.511	0.445	0.469	
III	Non eye-tiring-eye-tiring	0.044	0.092	0.854	0.739	Glare
	No glare- glare	0.292	0.032	0.830	0.775	
	Eigen value	7.11	3.23	1.32		
	Explanatory variable (%)	41.83	18.99	7.76		
	Accumulation variable (%)	41.83	60.81	68.57		

The first factor is "brightness", which is largely related to the brightness of the powder room and includes adjectives such as clear, looks well, pleasant, happy, bright and uniform. The second factor is called "emotion" as it is highly related to emotional adjectives such as warmth, looks good and natural. The third factor is called "glare" as it is highly related to the adjectives such as non eye-tiring and non eye-glaring.

Fig. 1 is a graph in which all the conditions are analyzed by factor. As a result, the luminous panel shows reduced brightness and glare. The Vertical bracket shows a high difference by factor. Despite the fact that it is positively evaluated for brightness, it is negatively evaluated for glare like combined luminaire. The combined luminaire has overall high evaluation figures in all the three factors. Table 5 shows the result of a factor analysis with the focus on those factors that are related and suggested those conditions which receive the best evaluation.

Table 5. Best conditions by factor
(Ev: vertical illuminance)

Factor	Analysis result	Best condition
Brightness	Vertical Bracket, Combined Luminaire > Luminous Panel Ev: 500lx, 600lx > 400lx	1:3, 4000K
Emotion	3000K > 4000K > 5000K	1:1, 3000K
Glare	Ev: 400lx > 500lx > 600lx Luminous Panel > Combined Luminaire > Vertical Bracket	Luminous Panel, Ev=500lx, 3000K

3.1.2 Comparison by Color Temperature

As a result of analyzing the conditions that have significant difference by color temperature, they show significant difference in emotion in all conditions. Emotion has no significant difference with vertical illuminance and luminaire type but has the highest relationship with color temperature (Fig. 2). Emotion has a higher evaluation with lower color temperature in an order of 3000K, 4000K and 5000K (Fig. 3).

Significant difference *p<.05, **p<.01, ***p<.001
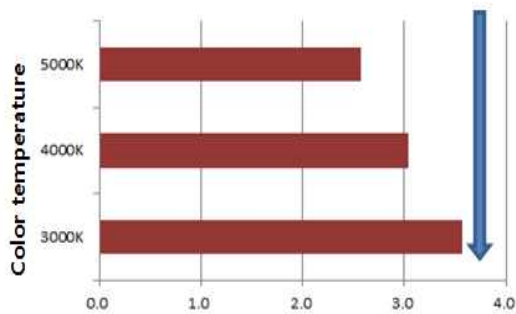
Fig. 2. Comparison by color temperature

Fig. 3. Comparison by color temperature of emotion factor

3.1.3 Comparison by Vertical Illuminance

Vertical illuminance shows a significant difference in brightness and glare factors, which tend to be opposite values (Fig. 4). In addition, the vertical illuminance 600lx shows a significant difference with 400lx but no difference with 500lx; therefore, 500lx can be considered the standard.
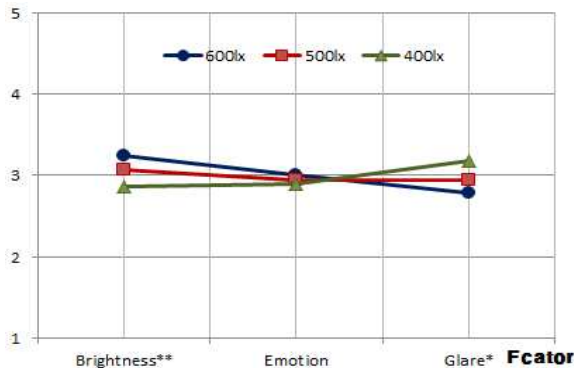
Significant difference *p<.05, **p<.01

Fig. 4. Comparison by vertical illuminance

Table 6. Best conditions of vertical illuminance by factor

Brightness	600lx-500lx-400lx
Emotion	N.S(no significant)
Glare	400lx-500lx-600lx

Significant difference *p<.05, **p<.01, ***p<.001
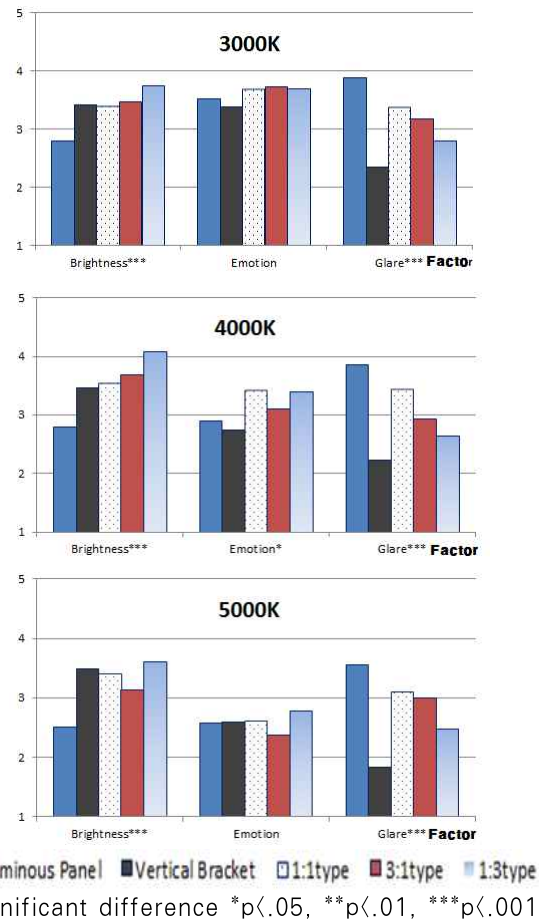
Fig. 5. Comparison by combined luminaire type

Table 7. Best conditions by factor for luminaire setups

Factor	Luminaire Type			
	Luminous panel, Vertical bracket	Luminous panel, Vertical bracket, 1:1, 1:3, 3:1	Luminous panel, Vertical bracket, Combined luminaire	1:1, 1:3, 3:1
Brightness	vertical bracket	1:3	combined luminaire	1:3
Emotion	no significant	1:1	combined luminaire	no significant
Glare	luminous panel	luminous panel	luminous panel	1:1

3.1.4 Comparison by Luminaire Type

Fig. 5 shows the result of the comparison of the five different luminaire types (luminous panel, vertical bracket, 1:1, 3:1 and 1:3). They display highly significant differences in the "brightness" and "glare" factors regardless of color temperature. 4000K, in particular, displays a significant difference with all factors. The 1:3 type is evaluated to show the best "brightness" regardless of color temperature while the 1:1 type is evaluated to show the best "emotion". The luminous panel is evaluated to have low "glare" but the vertical bracket has the highest "glare".

3.2 Subjective Evaluation Analysis

3.2.1 How Clear Do Faces Look?

The participants were asked to score how clear each part of their faces looked and the average scores of each part were analyzed. The evaluation does not have a significant relationship with vertical illuminance or color temperature, but it does with luminaire type. Overall, the vertical bracket is considered to be better than the luminous panel or combined luminaire.
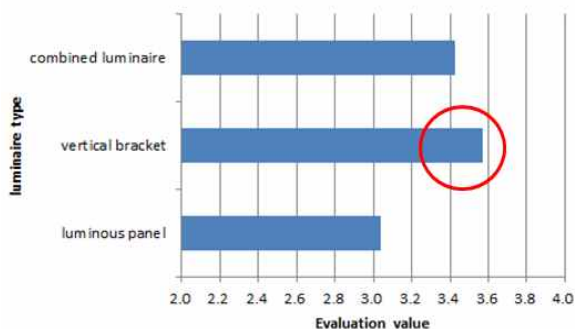

Fig. 6. Identification of face

The vertical bracket is the most influential experiment condition to vertical plane. It agrees with

the fact that vertical illuminance is the most important for seeing faces clearly.

3.2.2 How Easy is it to Classify Cosmetic Color?

A method to facilitate the classification of cosmetic colors is more related to color temperature than to luminaire type or vertical illuminance. A color temperature greater than 4000K is considered appropriate.
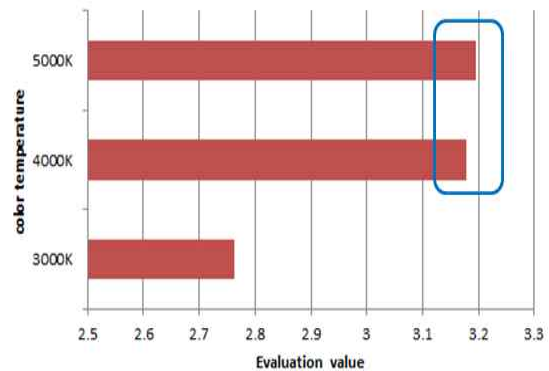

Fig. 7. Classification of cosmetic color

3.2.3 Satisfaction Evaluation

As a result of evaluating satisfaction with the overall lighting environment, brightness and glare, satisfaction with the overall lighting environment and that of brightness show the same trend.

Table 8. Best conditions by satisfaction

Satisfaction	Best condition
Overall lighting environment	Combined
Brightness	Bv luminaire(125+375lx), 4000K
Glare	Luminous panel, 400lx, 4000K

In the evaluation of satisfaction by luminaire type, the panel type shows high glare satisfaction but low satisfaction with overall lighting environment and brightness. The vertical bracket shows the opposite

result as compared to panel type. The combined luminaire is evaluated to have high satisfaction with overall lighting environment, brightness and glare.

3.2.4 Appropriateness Evaluation by Activity

There is no significant difference in the appropriateness evaluation by actions (basic make-up, color make-up, hair styling, accessorizing and clothing) according to lighting conditions. The best condition combinations include '500lx, 4000K and 1:3 combine luminous' and '500lx, 4000K and vertical bracket'. However, evaluation values are low when the actions are more visually delicate. Therefore, color make-up is considered to be the least appropriate.

Because in this experiment, the individual actions were allotted scan time, it is necessary to conduct further research regarding each action to produce more precise results.
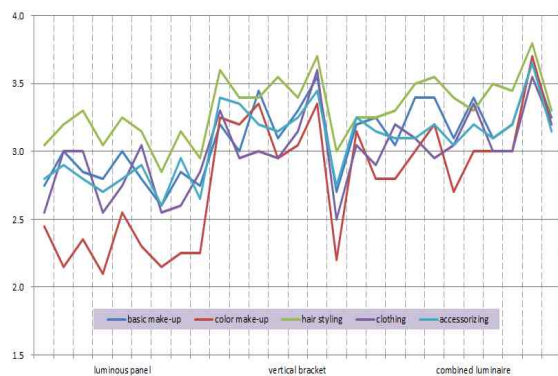

Fig. 8. Appropriateness evaluation by activity

3.2.5 Selecting Matching Shirt Color with Conditions

The participants were asked to evaluate which shirts would be more suitable after observing red shirts and blue shirts in the powder room. As a result, a red shirt is more suitable with 3000K and blue with 5000K.

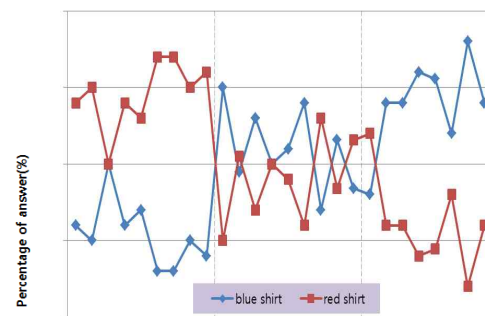Picture 2. View of the Experiment

Fig. 9. Selecting matching shirt color

3.2.6 Evaluation of Lipstick Color Classification

Five lipsticks with similar colors were used to create five groups. The participants were asked to find the same color after looking at the groups presented randomly. As a result, the best combination is the combined luminaire, 5000K and 500lx.

Table 9. Best conditions of lipstick color classification

Experiment condition	Best condition
Luminaire type	Luminous panel < Vertica illuminance < Combined luminaire
Color temperature (K)	3000 < 4000 < 5000
Vertical illuminance (lx)	400< 600 < 500

Picture 3. View of the Experiment

4. Summary

In this research, an SD evaluation and subjective evaluation were conducted in a mock powder room in order to determine the proper lighting environment for this kind of area. The summary of the results is as follows.

1. It was found that the best conditions for "brightness" are the '1:3 type and 4000K', those for "emotion" are the '1:1 type and 3000K' and the conditions for reduced "glare" are the 'luminous panel, vertical illuminance of 500lx and 3000K'.

2. Luminaire type and vertical illiminance are highly related to "brightness" and "glare" factors, which tend to be opposite. Color temperature is highly related to "emotion" while lower color temperature is evaluated highly.

3. The vertical illuminance of 500lx has no significant difference to 600lx; therefore 500lx can be used.

4. The vertical illuminance is maintained as 500lx in the experiment conditions for the combined luminaire. However, the best conditions differ according to the illuminance ratio of the luminous panel and vertical bracket.

5. In the evaluation of how clear faces look, the vertical bracket was evaluated to be the best and the lighting location is important. The evaluation of how easily cosmetic colors are classified found that it is easier when the vertical illuminance is over 4000K, which shows a relationship with color temperature.

6. The combined luminaire (1:3) and 4000K combination shows the highest satisfaction level with the overall lighting environment and brightness and the combination of luminous panel, 400lx and 4000K is appropriate to reduce glare. This result is almost the match of the SD Evaluation result.

7. The combination of the combined luminaire (1:3) and 4000K is found to be the best condition for all five activities. The result matches the best conditions for the "Brightness" factor, showing a mutual relations.hip

8. It was evaluated that red shirts go better with 3000K and blue shirts with 5000K and the best condition combination to classify lipstick color was found to be a combined luminaire, 5000K and 500lx.

5. Conclusion

People spend less time in powder rooms than in other living spaces such as living rooms or bedrooms but many visually delicate tasks are conducted in the space, making the lighting environment important. This study was conducted to determine the best lighting environment for powder rooms. As a result, the research found out that the lighting conditions such as luminaire type, vertical illuminance and color temperature could vary according to factor and use purpose.

It is hoped that this study can provide a reference for the establishment of lighting environments in powder rooms and that there will be many different follow-up studies such as regarding color classification ability test by age and experiments by activities.

References

〔1〕 Jang-Hyeon Lim, Hyun-Ji Kim, Hoon Kim, User Consciousness and Investigations on Powder Rooms in Apartment, KIIEE Annual Spring Conference pp.114-115, 2013. 5.

〔2〕 Jang-Hyeon Lim, Hyun-Ji Kim, Hoon Kim, Experimental study on the Evaluation of the Powder Room Lighting Environment, CJK Lighting Conference (Gwangju, Korea) pp.157-160, 2013. 8.

〔3〕 Hyun-Ji Kim · Seong-Jun Woo · Hoon Kim, Experimental Study on Living Room Lighting Environment for Residential Activities, Journal of the Korean Institute of Illuminating and Electrical Installation Engineers, Vol.27, No.1, pp.10-16, 2013.

〔4〕 IESNA, Lighting Handbook 18. Residential Lighting, 9th edition, 2000.

〔5〕 Randall Whitehead, Residential Lighting A Practical Guide to Beautiful and Sustainable Design Second Edition, John Wiley&Sons, Inc. 2009.

Biography

Hyun-Ji Kim

1994. 8 Yeungnam University, Dept. of Interior Environment Design, Masters of Engineering 2000. 6 Yeungnam National, Dept. of Housing Studies, Doctor of Science 2004. 3~ 2009. 2 Visiting Professor, Yeungnam University, Dept. of Family & Housing Studies 2011. 1~ Research Professor, Kangwon National University, Smart Lighting Research Center Research Interests: Interior Lighting, Light pollution prevention methods.

Jang-Hyeon Lim

2013. 8 Kangwon National University, Dept. of Electrical and Electronic Engineering, Masters of Engineering 2013. 9~ PhD Candidate, Kangwon National University, Dept. of Electrical and Electronic Engineering Research Interests: Interior Lighting, Light pollution prevention methods.

Hoon-Kim

Hoon Kim received an M.A. and Ph.D. degree in electrical engineering from Seoul National University in 1983 and 1988, respectively. He joined the Department of Electrical and Electronic Engineering, Kangwon National University, Chuncheon, Korea, in 1988, where he is now a professor. His current research interests include the optical design of luminaire reflectors and lenses, and the setting up of lighting energy savings policy and light pollution prevention methods. He is Chairman of the Korean Committee of CIE and Vice President of the KIIEE.