การสำรวจคุณภาพสภาพแวดล้อมภายในห้องเรียน กรณีศึกษา: ห้อง 1712 คณะวิทยาศาสตร์ มหาวิทยาลัยศรีนครินทร์วิโรฒ

Classroom Indoor Environmental Quality Survey Case study: Room 1712, Faculty of Sciences, Srinakharinwirot University

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บทคัดย่อ

ศาสตร์ด้านสภาพแวดล้อมอาคารได้ถูกเสนอขึ้นอย่างกว้างขวางจากผู้เชี่ยวชาญเพื่อเป็นแนวทางในการปรับปรุงอาคาร แต่ความรู้ดังกล่าวเป็นภาพรวมไม่สามารถประยุกต์ใช้กับทุกพื้นที่ การประเมินหลังการเข้าใช้อาคารถือเป็นแนวทางที่ทำให้เข้าถึงข้อมูลความสบายและความพึงพอใจของผู้ใช้อาคารได้เป็นอย่างดี ซึ่งเมื่อประกอบกับการวัดและการสังเกต การประเมินนี้จะเป็นวิธีที่สามารถบ่งชี้แนวทางในการออกแบบสถาปัตยกรรมได้ งานวิจัยนี้ประยุกต์ใช้วิธีดังกล่าวในการสำรวจความเห็นของผู้ใช้ห้องเรียน 1712 มหาวิทยาลัยศรีนครินทร์วิโรฒ เน้นศึกษาตัวแปรคุณภาพสภาพแวดล้อมภายในอาคาร ได้แก่ อุณหภูมิ, การมองเห็น, เสียง และคุณภาพอากาศภายในอาคาร เพื่อศึกษาปัญหาและเสนอแนะแนวทางในการปรับปรุงสภาพแวดล้อมภายในห้อง ผลการวิจัยยืนยันว่าความเห็นของผู้ใช้ห้องเรียนสามารถชี้วัดปัญหาของพื้นที่ได้อย่างมีประสิทธิภาพ ลักษณะของห้อง 1712 ยังไม่เหมาะสมต่อการใช้งาน ในแง่ของขนาด, ลักษณะช่องเปิด, งานระบบ และการบำรุงรักษา ทั้งนี้ปัญหาดังกล่าวอยู่ในระดับที่สามารถยอมรับได้ มิได้ร้ายแรง ข้อจำกัดที่สำคัญของงานวิจัยนี้คือผลจากการสำรวจสามารถชี้ร่องรอยแนวทางปรับปรุงห้องเรียนเพื่อสภาพแวดล้อมที่ดีเท่านั้น เนื่องจากเป็นเพียงความรู้สึกและความพึงพอใจของผู้ให้ข้อมูล ไม่ใช่การประเมินผลของสภาพแวดล้อมต่อสุขภาพหรือประสิทธิภาพในการเรียน แม้ความเห็นของผู้ใช้อาคารจะมีประโยชน์แต่จะต้องประยุกต์ใช้กับวิธีการอื่นหรือคำแนะนำของผู้เชี่ยวชาญเสมอ

ABSTRACT

While science about how to improve building environment has been widely presented by experts, it can be too generalized to suit every specific space. Post Occupancy Evaluation (POE) is one effective approach for in-depth study of occupants' comfort and satisfaction. Combined with measurement and observation, it can be used as a guide for architectural design. In this study, the method of POE was applied to survey lecture room no.1712 of Srinakarinwirot University, focusing on some of the Indoor Environmental Quality (IEQ) parameters: thermal, visual, aural and Indoor Air Quality (IAQ) aspects in order to study problems and suggest guidelines for indoor environmental

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improvement. The results confirm that the opinions of the occupants can effectively identify the problems of the space. The room was found inappropriate in size, apertures, systems and maintenance. The problems are generally acceptable, in other words they are not at a critical level. A significant limitation of this study is that the findings are only implications. Since the survey data are based on the sentiments and satisfaction of the occupants, they can only point the way for improvement of the room, they cannot directly indicate actual effects of IEQ on neither health nor learning performance of the participants. Although the survey data are useful, they should not be used to improve the room without other additional methods or consultation with experts.

คำสำคัญ: ห้องเรียน ความสบาย คุณภาพสภาพแวดล้อมภายในอาคาร
Keywords: Classroom, Comfort, IEQ

1. Introduction

Indoor Environmental Quality (IEQ) has been extensively applied for architectural design knowledge and green building rating systems in order to assess to what extent buildings can provide users' comfort while remain environmental friendly. Many pieces of research such as Barrett et.al. (2013: 678-689) confirm that IEQ influences students' learning performance, good IEQ has positive effects and bad IEQ has negative impact. To improve IEQ in classrooms, current knowledge was acquired and widely disseminated, but the main difficulty is that those standards and recommendations may not be practical. Most standards and recommendations are not only originated from countries in Europe and North America, which are located in warm to cold climates but also sometimes found to be out of date (Ramasoot and Fotios, 2009: 269-274.). Moreover, they have been obtained in controlled conditions and found to not be appropriate to design with built environment concept.

Previous studies, Catalina and Iordache (2012: 129-140) and Straka and Aleksic (2009: 532-536), found that real environmental design efficiency of classrooms can only be investigated by assessing buildings in use. While most built environmental research reported effectiveness of architectural design development by comparing quantitative data with standards, Supansomboon and Sharples (2013: 134.1-134.9) argue that recent recommendations cannot indicate users' comfort due to the fact that substandard conditions frequently provide them satisfaction. According to the study, there probably are larger acceptable ranges of occupants' satisfaction for the design with built environmental concepts such as daylighting. The idea of Post Occupancy Evaluation (POE) introduced for assessing buildings in terms of their sustainability has been used in previous research (Gupta and Chandiwala, 2010: 530-548 and Catalina and Iordache, 2012: 129-140). The method of questionnaire and the sensation scale of POE was also applied to this study for examining problems with built environmental design.

2. Materials and Methods

This study is a part of classroom occupants' satisfaction surveys of seven university classrooms in Thailand. The questionnaire-based survey focused on the occupants' opinions regarding their sensation and satisfaction in their own classrooms. Most of the questions ask the participants about IEQ parameters including thermal, visual, acoustic, Indoor Air Quality (IAQ) and overall satisfaction. The rest are about their personal information and any other comments for improving their classrooms. To better understand the results, physical surveys, classroom activity observations and lecturer interviews were included. Indoor and outdoor temperatures, relative humidity (RH), illuminance, and indoor carbon dioxide (CO_2) were measured in both occupied and unoccupied rooms, using two data loggers and a CO_2 meter. Acoustic measurement was excluded in this study due to measuring limitations.

The case study, room number 1712, is located on 16th floor of Building 19, Faculty of Sciences, Srinakharinwirot University (SC SWU). The dimensions of the room are 16.00 metre wide 8.60 metre long and 3.00 metre high. The appearance of the room shown in Figure 1 with all the lights turned off and the curtains fully opened. Containing washbasins, the room appears to be a laboratory in its original design. According to an interview, it has been used as a lecture room since its first operation. Students majoring in Jewelry, Department of General Science, are the main users of the classroom. The questionnaire participants are 77.72% of all users consisting of students from 1st to 4th year. The questionnaires were collected during the period from March to April 2016, which is the beginning of summer in Thailand.

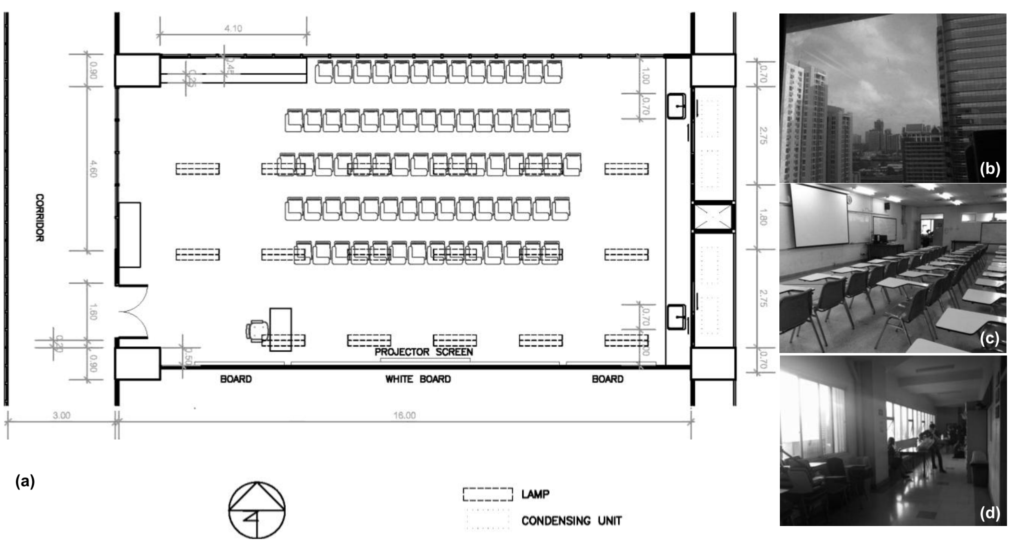

Figure 1 Appearance of room no. 1712: (a) floor plan, (b) outdoor view from main window, (c) room interior and (d) room corridor

3. Results

The results are divided into five categories: visual, thermal, acoustic, IAQ and overall satisfaction. The survey attempted to study all existing elements related to the parameters resulting in different numbers of questions. For example, there are questions regarding sensation and satisfaction for the thermal aspect, whereas not only sensation and satisfaction of brightness were questioned, but visual comfort of three tasks that influence visual satisfaction were also included. However, the measurements and the open-ended questions can either explain or emphasize the importance of the opinions of the users.

3.1 Weather data measurement

The measurement results of temperature, RH, illuminance and CO_2 rate are shown in Figure 2. The measurements were separately presented in the unoccupied room from 9 AM on April 11st to 9 AM on April 12nd, 2016 and the occupied room during working hours of on April 12nd, 2016. The room was actually occupied from 10 AM.

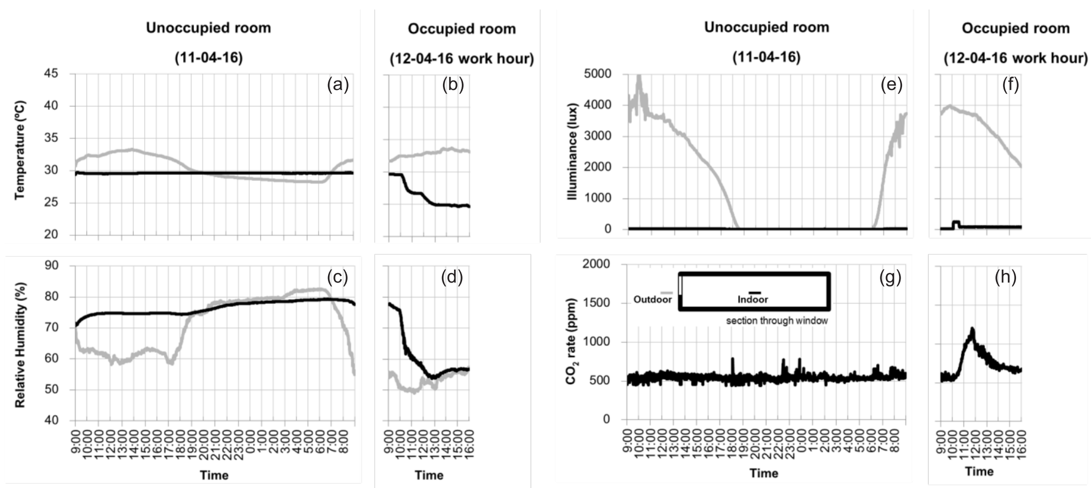

Figure 2 Weather data which was measured outside and inside room no. 1712 when it was unoccupied on April 11th, 2016: (a) temperature, (c) RH, (e) illuminance and (g) CO_2 rate compared to when the room was occupied during working hours on April 12th, 2016: (b) temperature, (d) RH, (f) illuminance and (h) CO_2 rate

Outdoor temperature (Figure 2(a) and (b)) was generally in the range between 29.00°C and 34.00°C. It reached its peak at about 2 PM while gradually reducing to the minimum in the early morning. Indoor temperatures of the unoccupied room were consistent at about 30°C. When the outside data logger recorded the air temperature, it ranged from 30.75 to 33.70°C. The inside temperature was reduced to 25.67°C in average when the air conditioning system (AC) was in operation. The temperature of the occupied room can differ slightly depending on the number of occupants. Outdoor RH level was generally less in the daytime. As can be seen in Figure 2(c) and (d), the minimum RH of the day can vary: 60% on April 11th, 2016 and 50% on April 12th, 2016. For example, it steeply increased to the range of 75-83% from 7 PM to 7 AM. It then dramatically decreased to the lowest level again at 9 AM. Indoor RH in closed unoccupied room insignificantly fluctuates for the entire day. The level approximated to the night time outdoor RH. When AC was operated, RH was reduced close to the rate of daytime outdoor RH.

Illumination pattern of the daylight is illustrated in the outdoor graph in Figure 2(e) and (f). Natural light was available from 6 AM to 6 PM. Without impact of direct sunlight, maximum outdoor illuminance occurring at 10 AM was about 4,000 lux. It can be much higher than 5,000 lux if the sun light penetrates the measured area. The daylight had insignificant effects on indoor illumination when the curtains were neither opened nor closed. The main source was artificial lighting that provided unchanged illuminance at 300 lux. The lighting was not switched on for all occupied time. The room was occupied without lighting for using a projector in the afternoon classes.

While CO_2 rate inside unoccupied room was about 446 ppm., the average rates from 800-1,200 ppm. occurred in occupied room (Figure 2(g) and (h)). The differences are due to the number of occupants between morning and afternoon classes. The CO_2 can reach the peak at 1,205 ppm. when approximately 40 students were inside the room.

3.2 Classroom observation and occupant survey

The room was generally used with AC and artificial lighting. Students were the key persons who operated the systems. Positions of lecture desks, AC evaporator and condensing unit and lighting layout are illustrated in Figure 3(a) and (b). According to the survey, the result shown in Figure 3(c) reveals that the majority of the students preferred sitting in the middle of the room, the middle row at the corridor side and the back row at the window side.

Figure 3 Sitting and equipment positions of the classroom: (a) room with light switched on, (b) room with light switched off, and (c) seat selection preference of participants

Thermal aspect

In terms of thermal sensation, the central air conditioning system was applied to cool the room. The AC appears necessary for the classroom as it is always on. As shown in Figure 4, the majority of the participants felt that the general temperature of the room was cool. 96.67% of them think it is acceptable. However, there were some comments revealing an inadequate condition of AC. Limited numbers of participants felt that the AC provided either a too warm or too cold thermal environment for the room. According to a classroom observation and lecturer interview, the temperature setting of the AC was hardly ever adjusted. The fact that some students felt either too warm or cold obviously resulted from two reasons. Apart from subjectivity, there is the distances of their sitting positions to the air registers could be the other reason. The further positions resulted in warmer sensation.

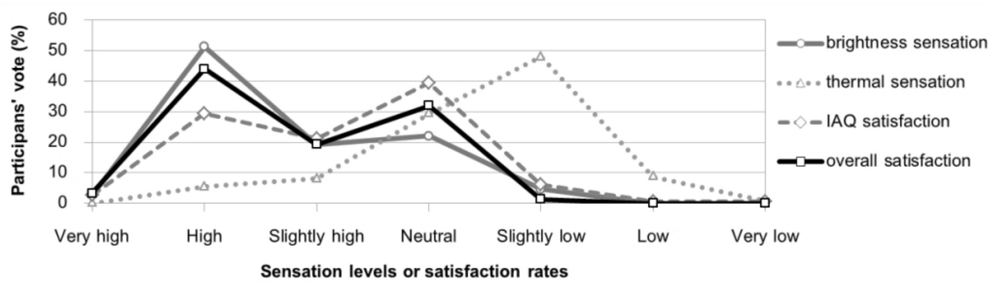

Figure 4 Students' levels of brightness and thermal sensation and rates of IAQ and overall satisfaction

Visual Comfort Issues

For visual comfort, the participants were questioned on two main sub-parameters, brightness level of the classroom and satisfaction for three visual tasks: lecture desk, whiteboard, and projector screen. Since the classroom windows are normally shaded by opaque fabric curtains, the classrooms usually need artificial lighting. According to the measurements, when the maximum external illuminance was 5,042.85 lux, the average indoor illuminance was 29.68 lux. The curtains, therefore, blocked almost all of the daylight. Artificial light, which appeared to be the main light source, hardly changed illumination levels. It was 244.20 lux on average. The majority of the participants rated the brightness of the room as 'bright' (Figure 4) and 99.33% of them thought that it was acceptable. Although most of the participants were not familiar with using natural light as seen in Figure 5(a), they think daylight can benefit their learning performance (Figure 5(b)).

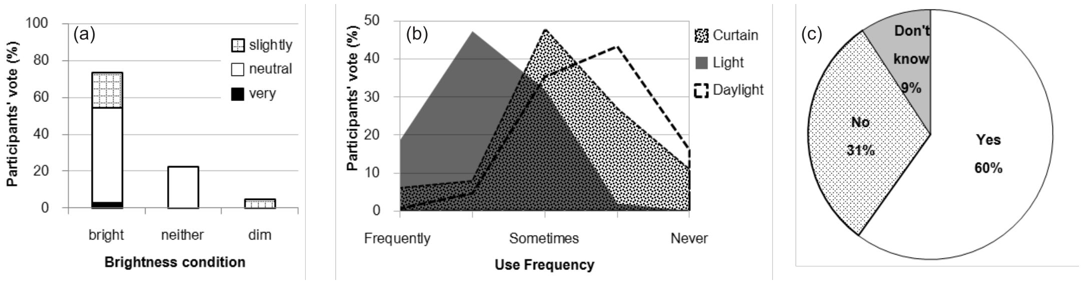

Figure 5 Students' responses: (a) rate of brightness sensation, (b) frequency of curtain, artificial light and daylight uses, and (c) attitude as to whether natural light has a positive effect on learning performance

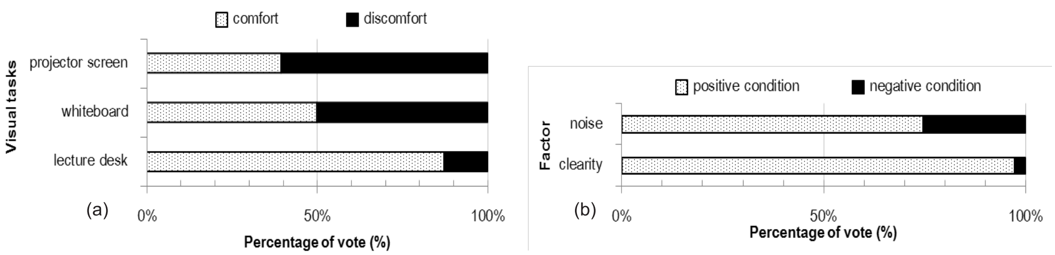

Figure 6 Percentage of participant votes for:
(a) visual comfort for three tasks and (b) classroom acoustic conditions.

The percentages of people who are comfortable with the visual tasks at the lecture desk, whiteboard and projector screen are 87.33%, 50.00%, and 39.33% respectively (shown in Figure 6(a)). Comments on how well they see the lecture desk are mostly about brightness. Due to the fact that the room will be too bright if the curtains are opened, the curtains were not usually opened although the users agreed that daylight can benefit their learning performance (details shown in Figure 5(c)). Artificial light is the main lighting source for the room. Lighting tone and layout are apparently not appropriate. It was suggested that the light should be of a warmer tone and that the front row should be separated. In addition, there were complaints that the room was too bright when the light is switched on and too dim when the lights were turned off while the projector was being used. In case of the whiteboard, the users' comments reveal that the illumination level is not the main issue of visual comfort. The excessive width of the room (16.00 metres) was probably the real cause of visual discomfort. A considerable number of participants pointed out that they hardly see the whiteboard when sitting at both ends of the front rows. Veiling reflection from lighting was also raised as a significant reason of discomfort. Unexpectedly, problems that are supposed to be less important, such as sizes of letters and colors of the whiteboard's markers, were frequently raised. As for the projector screen, the most significant problems were caused by the quality of seeing task: the images were unclear and discolored. The problems were reported even when the light was entirely switched off. Despite the fact that some comments about teaching materials such as improper letter size and contrast to background of images from the projector can be an insignificant issue as they probably depend on presentation skills of the lecturers, low quality of the projector was implied from those comments. Minor issues of the task relate to size of the screen and lighting condition. It was pointed out that either the screen is too small or most of the seats at the ends are too far. The lighting environment appears unsatisfactory when the projector is used either with or without the lights on. The lights not only disturbed the seeing task but also resulted in glare and veiling reflection on the screen. On the other hand, excessively high contrast between illuminated screen and dark environment also caused visual discomfort. Apart from the suggestion that the lights above the screen should be separately controlled, some students commented that instructors should have asked for better lighting control.

Acoustic problems

According to Figure 6(b), it seemed there were no acoustic problems when the room was being observed. 97.00% of the participants think they can hear clearly in the room. However, 25.00% of those people complained that there were disturbing noises inside and outside of the room. Screeching broken lecture desks, students' chatting and echoes from the microphone were reported as the main sources of internal background noise. Outside the room, there were people's footsteps in the corridor and noise pollution from the city. However, 99.33% of those surveyed rated the acoustic environment acceptable.

Room IAQ

When they were questioned about IAQ, the students reported that the room was not well-ventilated. In addition, there were problems with dust and bad smells. Some of the participants specified that those problems resulted from the air-conditioning system. A small number of participants complained that they also smelt chemicals from the room next door which is one of the department laboratories. The problems appeared less significant since a great majority (99.33%) rated the IAQ of the room acceptable. The majority thought that the IAQ level was in the range of 'Neutral' to 'High quality' as shown in Figure 4.

Overall satisfaction compared to four IEQ parameters

Figure 7 illustrates a comparison of the acceptable rates of four IEQ parameters and overall satisfaction for seven classrooms in different universities in Thailand. According to Figure 7(a), the overall satisfaction is obviously lower than the acceptable rates for all parameters in general. Room 1712 of SC SWU which is a classroom that this paper focused on, was shown in the middle using black color. For room 1712, a considerably high number of students rated 'acceptable' for all parameters while the average satisfaction level is just a little higher than 'slightly satisfied'.

When analyzing correlation of five parameters in Figure 7(b), it was found that visual and acoustic satisfaction rates correlate with each other (0.97) while the thermal aspect was found to correlate closely with the IAQ (0.77). However, the overall satisfaction was at 0.60, a moderate correlation level. This reveals that there might be other factors influencing the participants' satisfaction. It can be explained by data provided in the open-ended question that participants were asked to write whatever they want as suggestion to improve their classrooms indoor environment.

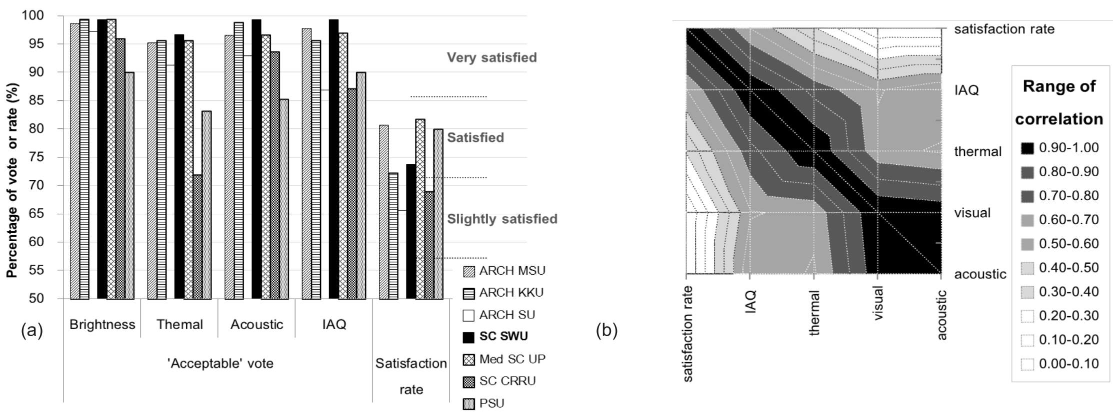

Figure 7 Students' acceptability rates for four IEQ parameters and overall satisfaction rate in seven university classrooms in Thailand: (a) percentage of vote or rate of SC SWU comparing to other six classrooms which can imply priority of the four IEQ parameters in overall satisfaction, and (b) correlation of the five factors using data from seven classrooms which can show influences on each parameters.

<u>*Additional comments*</u>

Apart from suggestions already mentioned, redecoration and more frequent maintenance were suggested. Most frequently, requests are for fixing or changing room elements or furniture such as curtains, lecture desks and doors that not only cause noises but also have improper features. For instance, lecture desks should either be bigger or include storage lockers. Curtains should be replaced with blinds, which can let in more daylight. There are some comments about cleanliness. It was suggested that the room and AC should to be regularly cleaned due to excessively high amounts of dust. Other comments are probably not directly related to the occupants' comfort but to issue that influence their personal satisfaction. Teaching devices, for example, should be more technologically advanced, such as using an interactive board instead of a screen or conventional whiteboard.

4. Discussion

Apart from its excessive width, room 1712 was fully controlled with building systems and connected to an enclosed corridor. Due to these specific features, thermal and acoustic aspects can be better controlled, although a lack of natural ventilation and daylighting can be expected. According to the survey, some uncomfortable conditions occurred. The following design factors were considered for finding better solutions.

4.1 Possibility of exposure to outdoors

Natural ventilation has been found necessary as it can benefit the thermal comfort, energy conservation and IAQ of the space. For room 1712, openings were provided although it was designed for using mechanical systems. It may be difficult to naturally ventilate the rooms connected to closed corridor but there are more important reasons for keeping all openings closed. The possibility of exposure to outdoors will be discussed in each aspect.

Ambient weather vs. Air conditioning system

Although it is found that people in hot humid climates can accept higher temperature and relative humidity than standards, the students felt comfortable in the air conditioned environment. Representing comfort zones, operative temperatures of 21.00-28.00°C with various RH values are recommended by ASHRAE while Olgyay's comfort zone is in the ranges of 21.00-30.00°C of temperature and 35.00-65.00% of RH. However, Jitkhajornwanich (2006) suggested that hot-humid climate comfort zone can be shifted into 25.60-31.50°C air temperature ranges and 62.20-90.00% for RH. For classrooms, an average room temperature higher than 22°C was recommended by Norback and Klas, (2008: 21-30). Khadijah and Tazilan (2013) reported a survey in Malaysia that the general thermal environment of the observed classroom was rated between 'warm' and 'hot' on the seven point ASHREA scale. The highest acceptable temperature was suggested at 26.50°C. Occupants in hot-humid climates appear to be able to accept warmer weather than standards in passive spaces. In air-conditioning spaces, the expectation and perception of occupants were found to influence thermal sensation (Jitkhajornwanich and Pitts, 2002). In rooms with AC, occupants appear to prefer a lower temperature than their preferences in a passive environment. Moreover, they also over estimated warmer thermal sensation in the non-AC adjacent space of the rooms. According to the survey of room 1712, outdoor air temperatures during summer which were at least 2°C above the acceptable rates cause difficulty in applying natural ventilation. The consistent minimum room temperature at about 25°C and the high percentage of thermal acceptable rate reveal that the AC appeared to work properly for providing thermal comfort, thus there was no need to use other cooling systems. Windows may be opened for two reasons: when electricity or the AC is not available and, on some days, during favourable weather conditions which hardly ever occur.

Availability of daylight and visual connection

Due to the excessive room width, natural light alone provided insufficient illumination level and too much brightness contrast resulted in visual discomfort. Bright environment must be controlled for proper seeing visual tasks. In addition, opaqueness of the curtains, obstruction by AC condensing units and distance from student seats to the windows did not allow visual connection to the outside. For these reasons, the participants almost never opened the curtains. As the curtains were not opened, the windows were also closed.

Pollution control

Classrooms are commonly required to be closed for pollution control. In terms of air pollution, the fact that room 1712 was at a high level above ground allows for the opening of windows as air pollution declines with height. However, a sealed room is required for acoustic reasons. Although the room was closed noises still came in, but fortunately at an acceptable level. Acoustic problems can be severe for rooms with opened windows.

4.2 Visual comfort

Three impact factors influencing visual comfort in general are lighting quality, capability of the human visual system and clarity of seeing task. For classrooms, there are three main visual tasks that need different lighting conditions. Limitation of the human visual angle and distance causes different affection the tasks when the sitting position is changed. Apart from the illumination level, a satisfactory lighting environment is necessary. Daylighting has been found to be important for improving lighting quality.

Three visual tasks and lighting conditions

Regular brightness conditions appeared to be proper in general use, but less necessary for seeing remote vertical tasks like whiteboards and projectors. While the majority felt comfortable with seeing tasks on the lecture desk with artificial light, they felt discomfort when seeing tasks on the whiteboard and using the projector. Illuminance of 300 lux from artificial light can satisfy participants when using the lecture desk. The illumination level may also be appropriate to the whiteboard if there is no veiling reflection. Less than 50 lux of illuminance, which was the general condition for using the projector, appeared to be the optimal condition but the majority rated it as uncomfortable when looking at the projector screen. If the quality of the projector and presentation slides were the main reasons, they can easily be solved without improving the room features. However, the suggestion of separate controls for front row lighting implies requirements of higher illuminance for the remaining area. When incident and reflecting angles on the glossy surface of the whiteboard were considered, a light source too close to the whiteboard possibly was the main cause of veiling reflection especially for the front area of the room. As a result, the shape and size of the room can be difficult not only for re-arranging the lighting lay-out but also for avoiding the occurrence of veiling reflection. A greater length of the room is required for providing more distance between the whiteboard and the student seats. The solution allows for a more separated lighting lay-out, resulting in more efficiency for lighting control. Furthermore, reduction of the width of the seating area can also avoid far end seats which were riddled with problems.

Daylighting

Basically, natural light has been considered important for human well-being and students' learning performance. Most of the users said they preferred daylight but they were rarely exposed to it. According to Supansomboonand Sharples (2013), natural light is good for general activities in the classroom and for seeing tasks on lecture desks. Apart from the fact that the curtains and windows were always closed, the brightness in the room was reduced by the excessive width of the room and improper internal shading devices. The area next to the window, which benefits the most from the daylight, was left unused because the board, screen and student seats were positioned in the middle of the room. For utilizing natural light, the classroom façade and sitting position should be improved.

4.3 Aural comfort

The acoustic aspect has a very high number of 'Acceptable' votes. Interestingly, votes of poor acoustics and disturbing noise are lower than votes of 'Unacceptable' acoustic environment. It reveals that, although some people did not hear clearly and were disturbed by noises, they voted 'Acceptable'.

According to a recommendation of National Institute on Deafness and Other Communication Disorders, the upper limit of comfortable noise level is 60 dB. Meeting the standard, occupied noise levels were found between 47-62 dB, from one person talking to a group working with movement (Shield et.al., 2010). Similarly, noise levels of AC systems are 50 dB in average. Apart from insignificant levels of disturbing noise, the acceptable background noise from AC can reduce occupants' awareness of other noises at the same volume level. Noises in excess of 60 dB noises occurring in classrooms have been confirmed as annoying. These levels of noise interfere with conversation, therefore, they are definitely noticeable for the room occupants. Although no noise measurement was obtained in this study, acoustic problems of the room were insignificant according to classroom observation and lecturers' interviews. Similar to the result of the questionnaire shown in Figure 6(b), it is generally a good acoustic condition in terms of noise and clarity.

Chan et.al. (2015) affirmed that the greater the age of the students, the less noise will be produced in the classrooms. Being a university classroom, there would be less noise disturbing learning activities in room 1712. Without a sound absorbing surface, there was no effect from reflection inside the room. The room proportion which appeared to be problematic for other aspects, rather benefits the acoustic quality of the room. The limited room length allows for shorter distances between the lecturer and the audience. However, echo problems were revealed by audible footsteps from the corridor. Acoustic insulation of the intermediary wall and its openings was obviously inadequate.

4.4 Indoor Air Quality

The fact that the acceptance vote of the IAQ for Room 1712 is remarkably high compared to that of other classrooms (see Figure 7(a)), reveals that the room has certain appropriate features. However, lack of ventilation, pollution from AC and dust were repeatedly mentioned in the survey. The significance of these issues is required to be investigated.

Room density and CO_2 rate

According to Matsler (1966), Castaldi (1969) and Wood (1970), the area of classrooms for 50-60 students should be between 60.00 and 108.00 square metres. By this standard, the size of a public university classroom in Thailand should be at least 1.50 square metres. The area of 99.22 square metres of room 1712 not only meets the standard but also has been usually occupied by fewer than 50 students. The students' satisfaction with the room area was probably higher than that of other case studies, particularly in terms of IAQ. However, the maximum CO_2 rate, which is higher than the ASHRAE standard 62-1989 of 750 ppm. for classrooms, can be a problem. The critical level of CO_2 at 800 ppm suggested by Norback and Klas (2008: 21-30) is also too strict for a fully occupied room. The rate reportedly has less impact if the room temperature does not exceed the standard of 22°C. The maximum CO_2 rate of room 1712, therefore, still has an impact on Room 1712. The impact is probably revealed by comments of 'No ventilation', which express the need of fresh air. Apart from occupants' dissatisfaction, negative effects were found in previous studies. While lower attendance of students was found in six schools in the USA (Shendell et.al., 2004: 333-341), an excessively high level of CO_2 results in tiredness, reduced learning ability and sickness of occupants in the experimental classrooms of Norback and Klas (2008: 21-30).

Impact of AC

According to participants' comments, the quality of AC systems influences not only people's thermal sensation but also affects room acoustics and IAQ. As can be seen in Figure 7(a), the percentages of the students' satisfaction in room 1712 with room thermal, acoustic and IAQ aspects are the highest when compared to those of other case studies. According to surveys, people who usually occupy classrooms with improper AC generally express their displeasure by voting thermal dissatisfaction, suggesting noise, dust and smell from the AC as principal causes of acoustic and IAQ dissatisfaction. The problems possibly depend on the age of the buildings and the availability of AC. As shown in Figure 7(a), the case studies where participants rated the lowest score for IAQ are Arch SU which is located in the oldest building and SC CRRU which contained classrooms without AC. The AC of room 1712 appeared to work better than other case studies. However, RH of room

1712 exceeded 50-60% recommended by Sahanavin (2012: 367-380) who assessed microorganisms in the classrooms of another campus of Srinakarinwirot University. The research reported excessively high amounts of fungi on room surfaces and bacteria mainly from AC that are caused by an unacceptable high RH. These microorganisms can be one of the main reasons of bad smell noted by the occupants. They possibly have negative effects on the occupants' health.

Occurrence of dust

Although the room 1712 was less exposed to the outside, dust was frequently reported as a main indoor air pollution. A study of Poupard et.al. (2005: 2071–2080) reported that particles in the air can be very much generated by human activities. Apart from indicating the occurrence of dust, the participants also suggested the classroom to be regularly cleaned. It can indicate a low frequency of the cleaning schedule. A study of five classrooms in Hong Kong (Lee and Chang, 2000: 109-113) confirmed dust as one of the main IAQ problems. Although there is no evidence of the effect of general dust on people's health, dust mites which can grow perfectly in the RH range of the classroom has been known to easily cause allergies.

Consequently, the quality of indoor air in room 1712 was reduced because of lack of ventilation, AC maintenance and room cleaning. Density of the room appeared not to be a problem. Theoretically, good ventilation can solve the problems of excessively high amounts of CO_2 and RH. The users' comments asking for better ventilation of the room appear to point to a proper solution. Additionally, it was suggested that the room and AC be regularly cleaned in order to reduce fungi and bacteria.

4.5 Holistic consideration

Previous studies such as Lee et.al. (2012: 238-244) and Trebilcocket al. (2012: 8.50.1-8.50.6) generally confirmed the impact of IEQ parameters on students' learning performance but in a different order. For instance, while Theodorson (2009: 286-290) and Barrett et.al. (2013: 678-689) ranked lighting as the first priority, Lee et.al. (2012: 238-244) reported that visual environment has less influence than aural and thermal ones. In other perspectives, IAQ, has been found most related to the students' overall satisfaction in this study. Thermal was found correlated to IAQ. It can be explained using information in Figure 7(a). The lowest overall satisfaction was rated for Arch SU which gained the lowest IAQ score. The fact that ARCH SU also gained low scores for the other parameters may provide insufficient evidence for claiming a relationship between IAQ, thermal and overall satisfaction. Less satisfaction of SC CRRU occupants can confirm significance of the factors. While SC CRRU Participants rated high scores for other parameters, they rate thermal and IAQ substantial lower than the other studies. Therefore, thermal discomfort and poor IAQ appears most critical for rating the overall satisfaction in this study. Visual and acoustic aspects were found most correlated to each other but less related to the rest. Considerably high scores were rated for visual and acoustic parameters in most case studies although many complaints were submitted. It is possible that occupants did not give priority to the parameters but the main reason may be the fact that a fair quality of visual and aural equipment was maintained for facilitating learning activities. However, Kruger and Zannin (2004: 1055-1063) suggested that the integration of acoustic, lighting and thermal design can better provide occupants' comfort than considering one parameter separately. Although some parameters were rated as priority, all IEQ parameters were influenced by the same architectural design parameters. Holistic consideration is necessary.

5. Conclusion

Architectural designs appear to have a great impact on the occupants' comfort for all parameters. Visual comfort depends on the room's width. Exposure to the corridor and AC influence their satisfaction of thermal, acoustic, and IAQ aspects. Additionally, different numbers of occupants probably results in different rates of satisfaction of IAQ.

The occupants' opinions and comments clearly identify the problems of Room 1712, which concern room width, daylighting, AC and ventilation. Some of the suggestions are that the width of the seating area should be reduced and moved closer to the window, windows and blinds should let in more natural light and fresh air, and AC should have better relative humidity control and better ventilate the room. For more effective implementation, room and AC cleaning instructions and schedules should be integrated into the building maintenance plan.

Due to the fact that this study focused on satisfaction instead of students' performance, the findings may not contradict previous research but people's satisfaction can point to the solutions. It is possible that they may fulfil their needs rather than create an appropriate environment. However, occupants' additional comments are necessary not only for better understanding the students' satisfaction but also for obtaining in-depth information. Architectural research in this field and suggested guidelines for building owners are still essential for developing classrooms. Considered with design principle, opinions of building users can be an effective guidance for improving the learning environment.

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