

# Effect of External Ground Surface Materials on Indoor Thermal Comfort

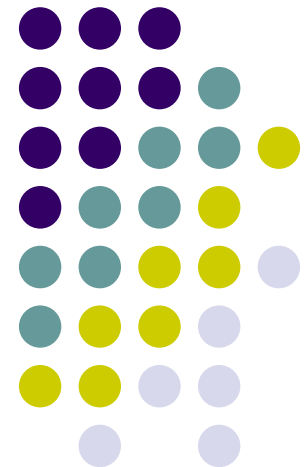
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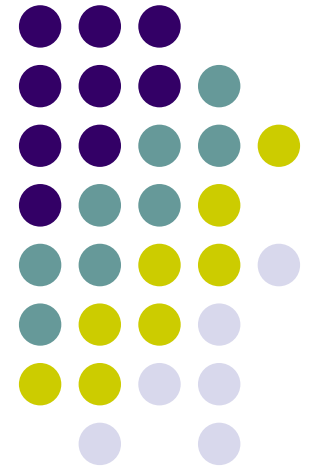
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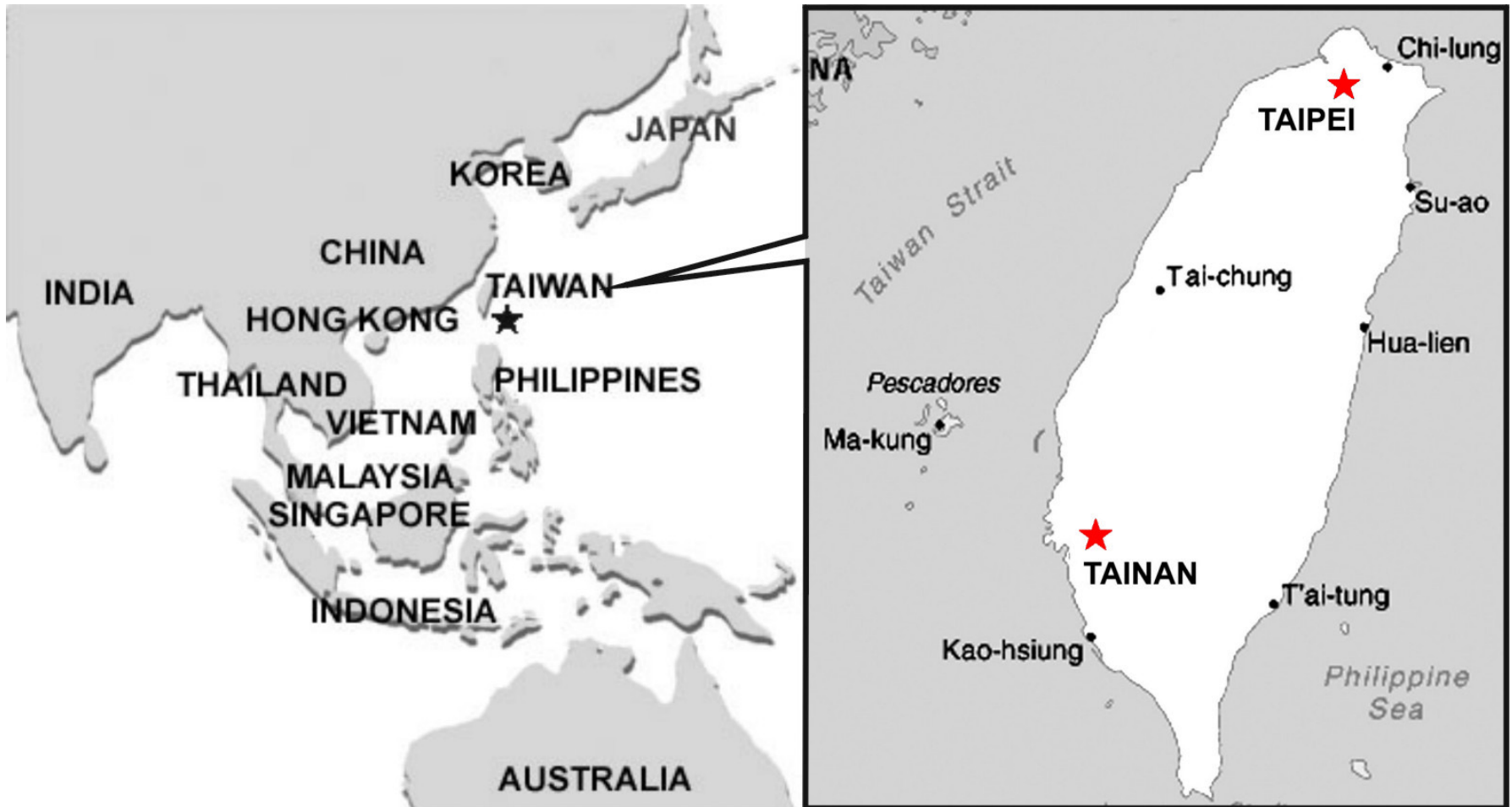
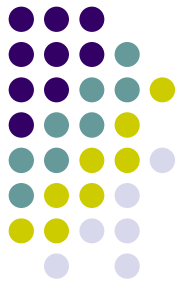


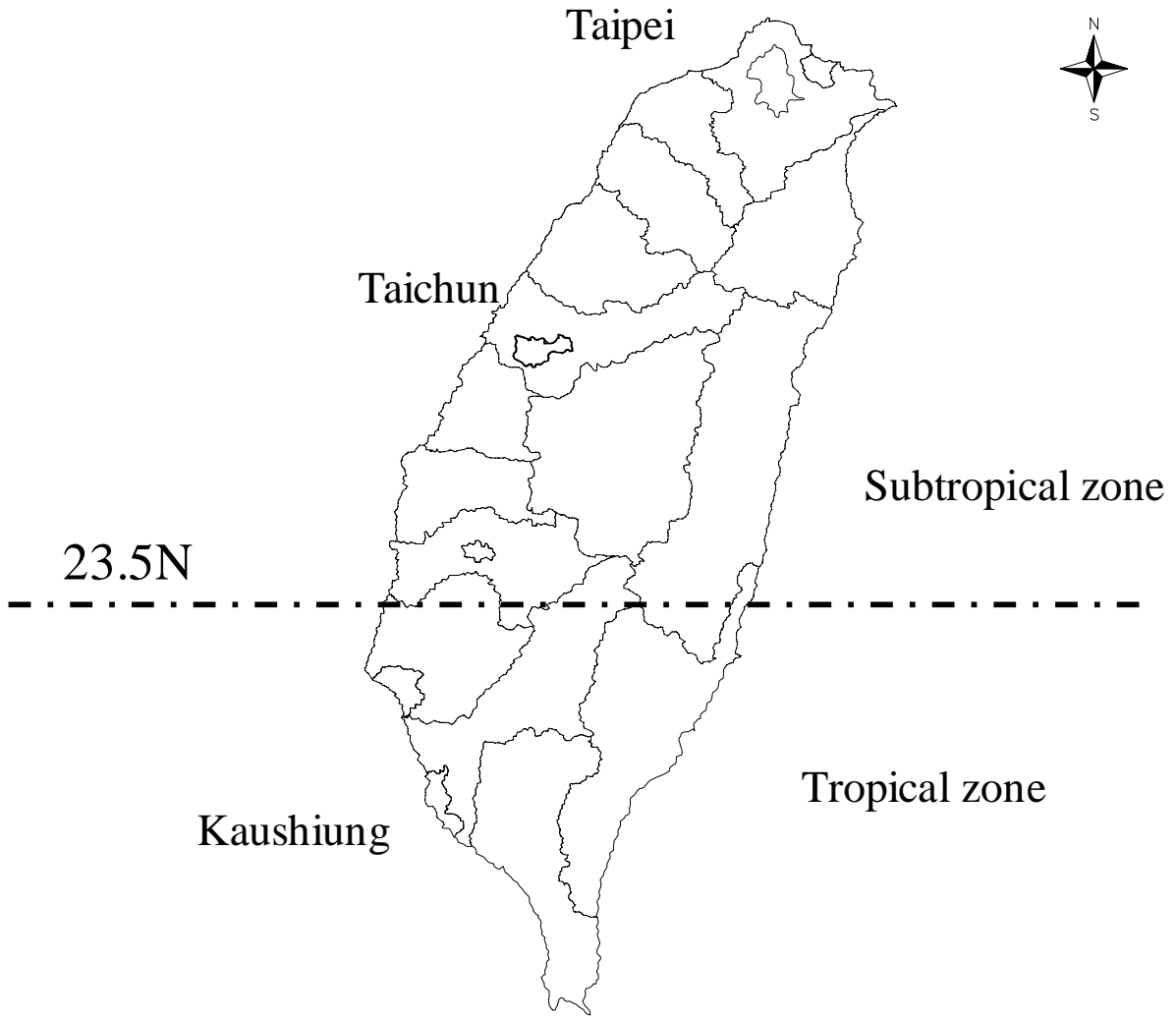
# INTRODUCTION

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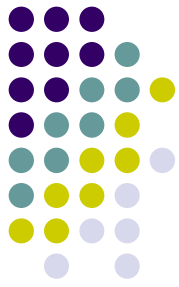
# Where is Taiwan



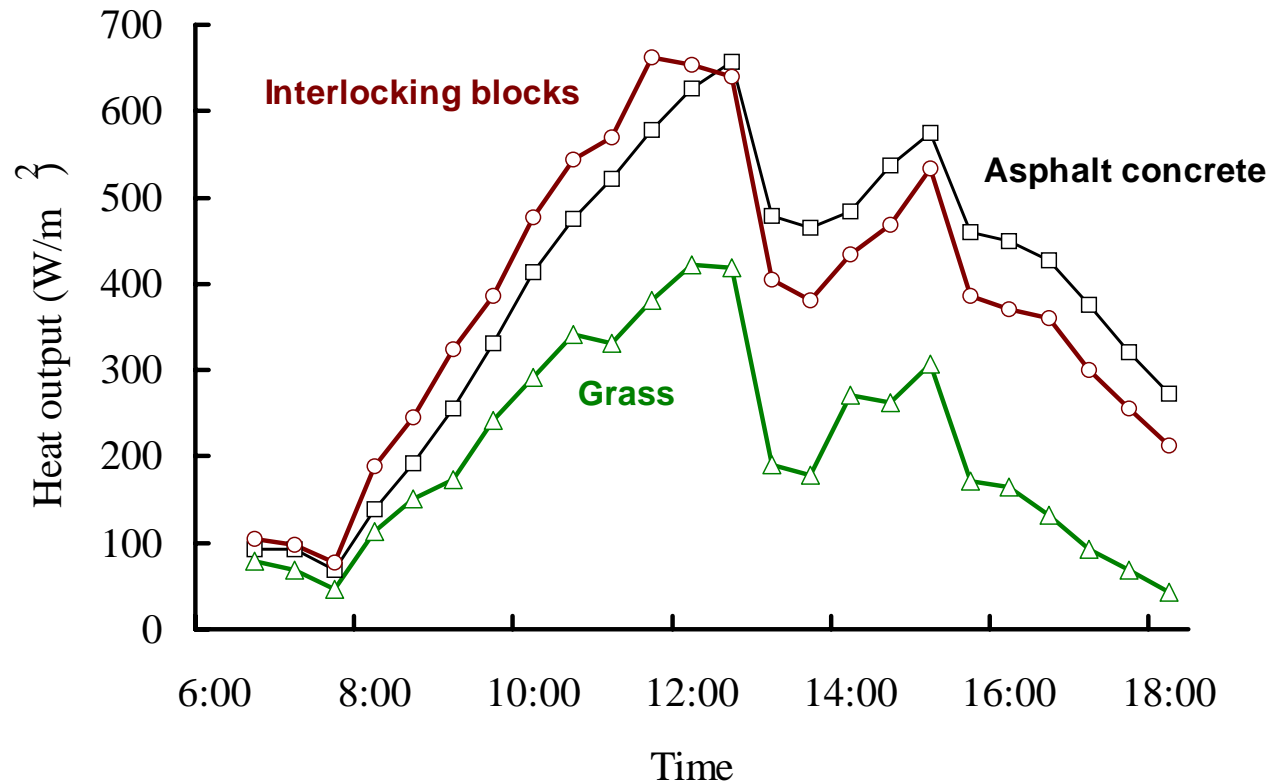


| Season   | Winter |      | Spring |      | Summer |      |      | Fall |      | Winter |      | Average |      |
|----------|--------|------|--------|------|--------|------|------|------|------|--------|------|---------|------|
| Month    | Jan    | Feb  | Mar    | Apr  | May    | Jun  | Jul  | Aug  | Sep  | Oct    | Nov  |         | Dec  |
| Northern | 15.8   | 15.9 | 18.0   | 21.7 | 24.7   | 27.4 | 29.2 | 28.8 | 27.1 | 24.3   | 20.9 | 17.6    | 22.6 |
| Central  | 16.2   | 16.8 | 19.4   | 23.0 | 25.7   | 27.5 | 28.5 | 28.0 | 27.2 | 24.9   | 21.4 | 17.8    | 23.0 |
| Southern | 17.4   | 18.2 | 21.1   | 24.5 | 27.0   | 28.4 | 29.0 | 28.5 | 28.0 | 25.9   | 22.4 | 18.8    | 24.1 |

# The influence of pavement on outdoor environment



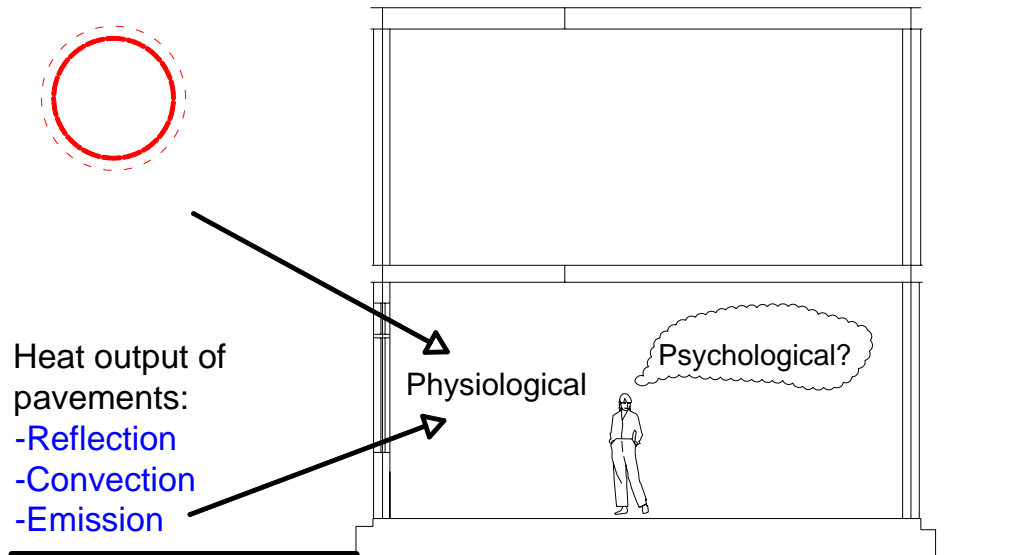
- The heat output of grass was consistently lower than that of artificial pavements



# How outdoor pavements influence indoor thermal comfort?

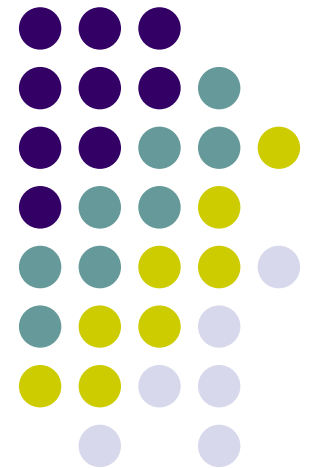


- When buildings are surrounded by artificial or impermeable pavements, the external ground surface material..
  - produces enormous heat output which increases outdoor temperature
  - and subsequently increases indoor air temperature indirectly

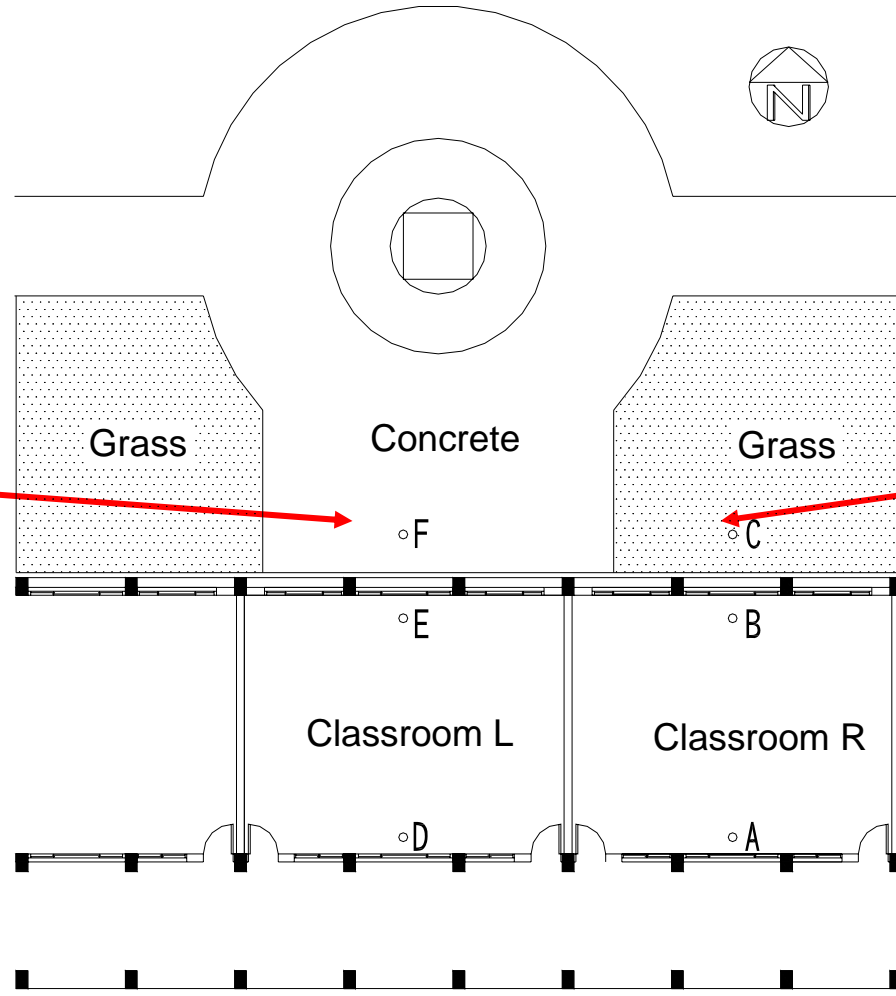


# 2. METHOD

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# Subjects

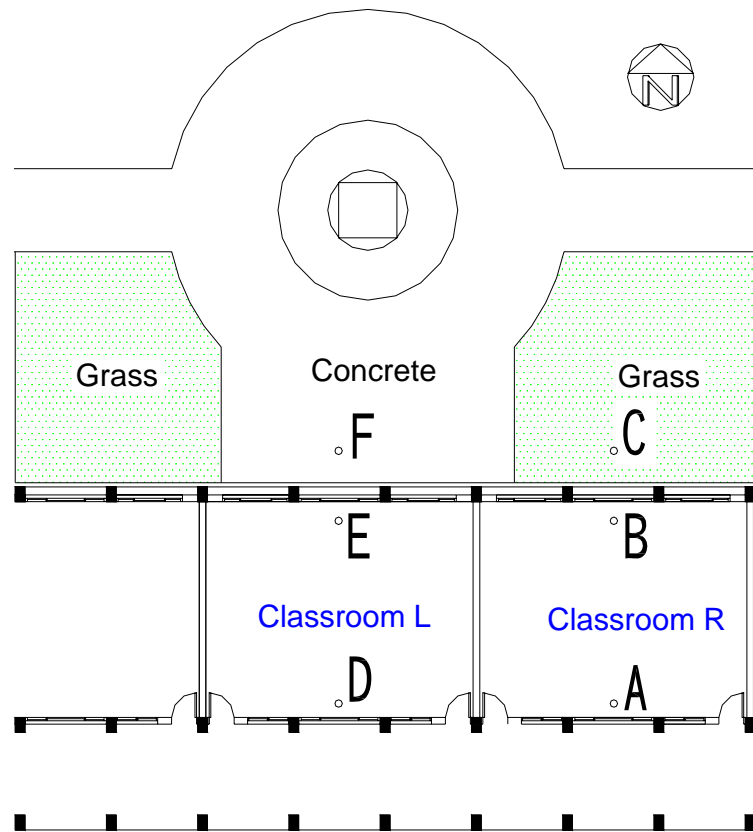


- Two adjacent classrooms sharing the same space form and characteristics.
- The two classrooms only differ in external ground surface material.

# Field experiments



- Both the measurements & questionnaires were conducted simultaneously at six indoor and outdoor points.



# Measurement

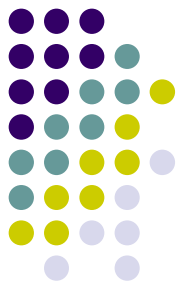


- Measured factors
  - air temperature ( $T_a$ )
  - global temperature ( $T_g$ )
  - ground surface temperature ( $T_{surf}$ )
  - relative humidity (RH)
  - wind velocity ( $V$ )
  - Global radiation ( $G$ )
- instrumentation specifications met the standard of ASHRAE(2001, 2004)

# Indoor measurement point



# Outdoor measurement point

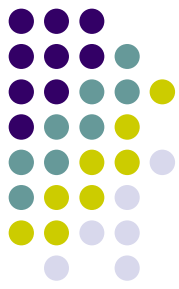


公告

國立中央大學於一月二十二日(星期日)上午  
七時至下午五時於文化中心廣場、伊凡克館前、  
路光館、一樓即利宜前方便進行各項測量，  
請貴校協助記錄儀器，請各知照。

2014.1.22

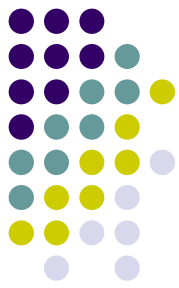
# Content of questionnaires



- Fundamental data
  - gender, age, clothing (CLO) and activities (MET)
- Subjective thermal comfort data in ASHRAE scale (-3~3: very cold~ very hot)
  - Thermal Sensation Vote (TSV)
  - Humidity Sensation Vote (HSV)
  - Wind Sensation Vote (WSV)
  - Sun Sensation Vote (SSV)
  - Thermal preference
  - Thermal comfort acceptability
- Objective thermal comfort indices
  - $ET^*$ ,  $SET^*$ , PMV and PPD

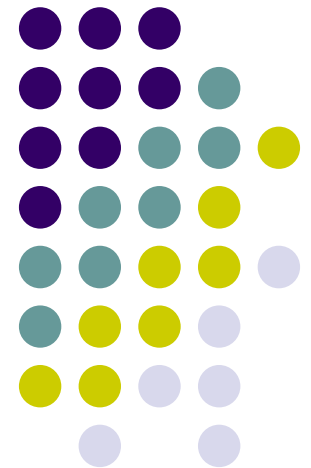


# Procedure



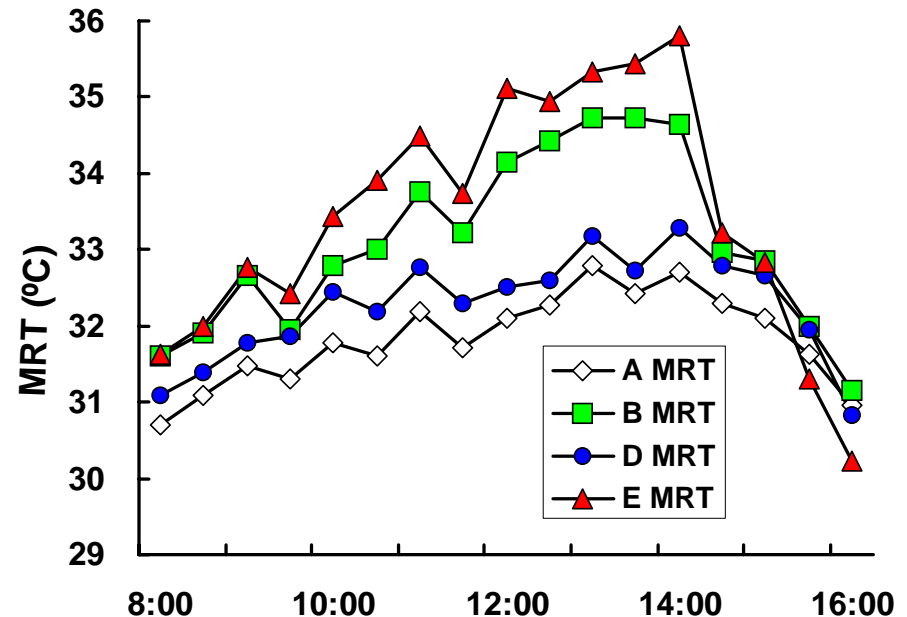
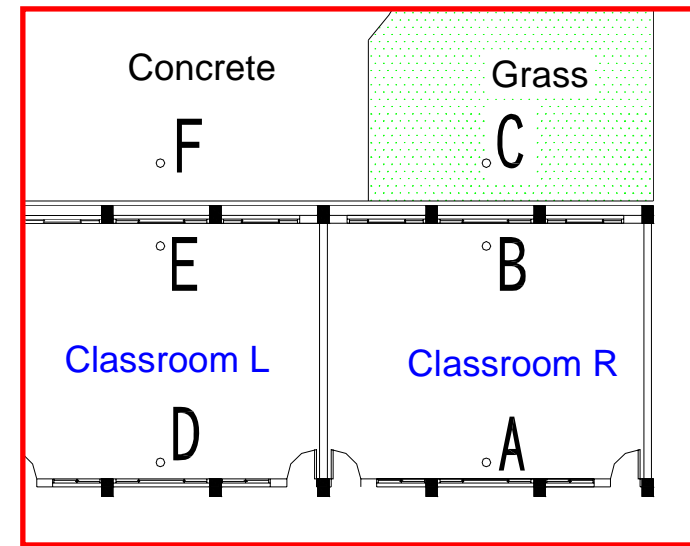
- The data were gathered at one-minute intervals from 8:00 to 17:30 for six points.
- The questionnaire investigation was performed at 8:00, 9:00, 10:00, 11:00, 13:00, and 14:00 for the four indoor points with the respondents being students. A total of 450 effective questionnaires were obtained.

# RESULTS



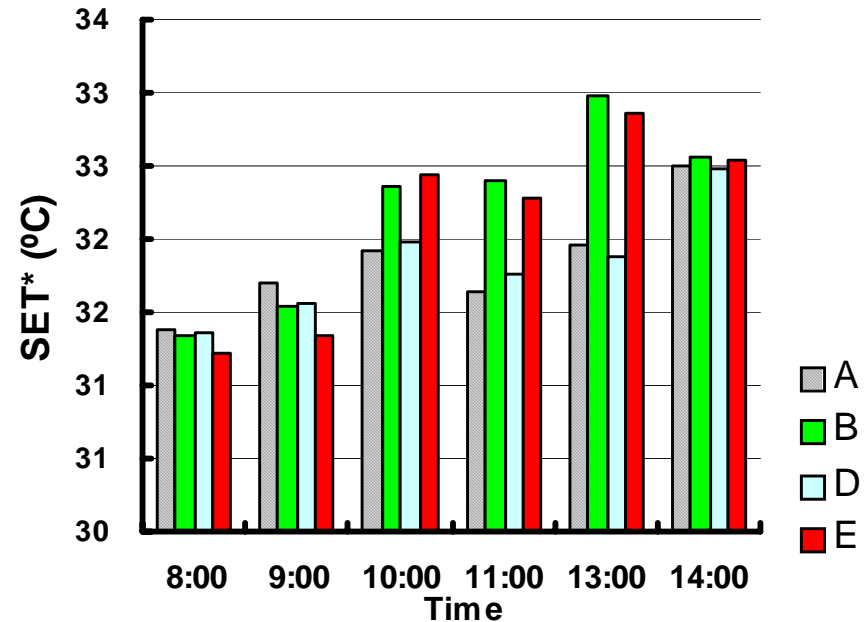
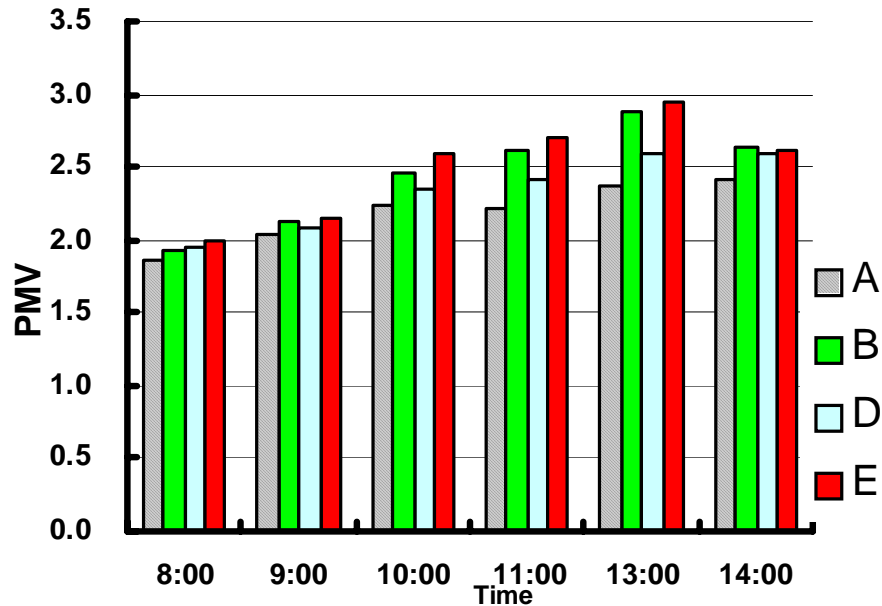
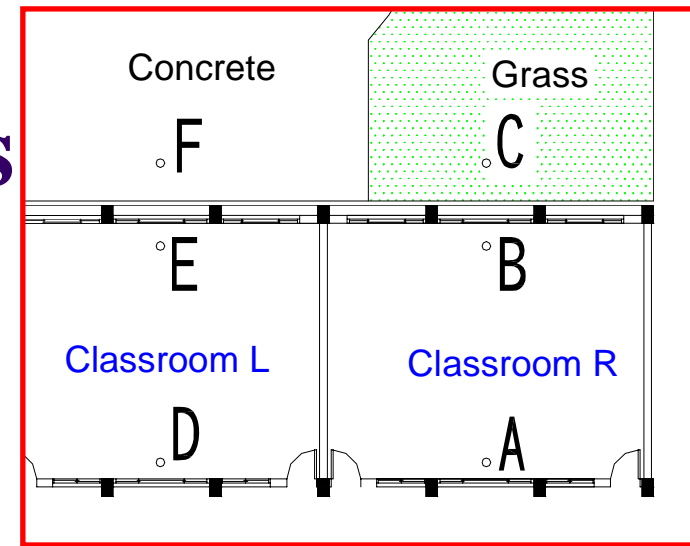
# MRT variation

- MRT :
- point E,B >> point A, D
  - (near corridor) (near outside)
- point E > point B
  - (concrete outside) (grass outside)



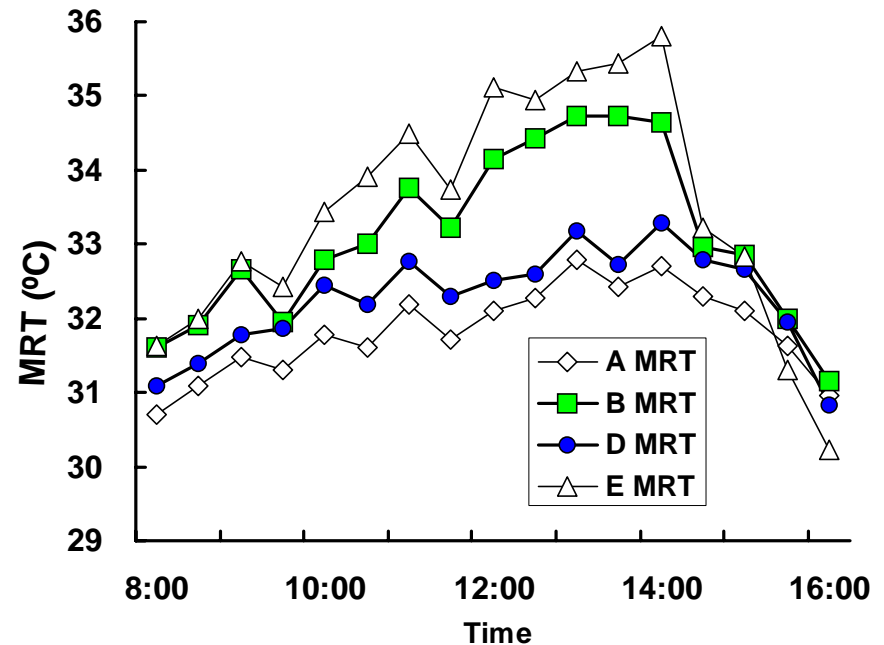
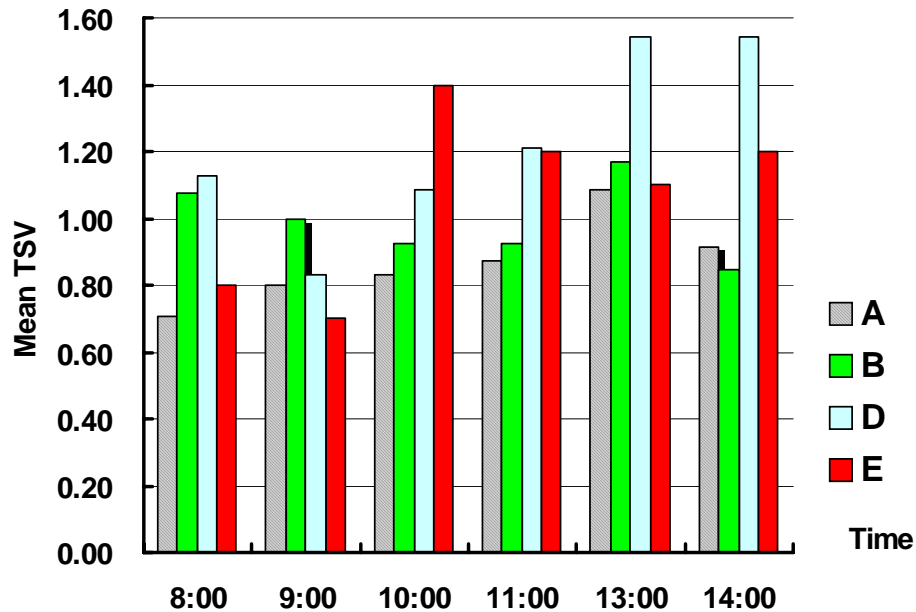
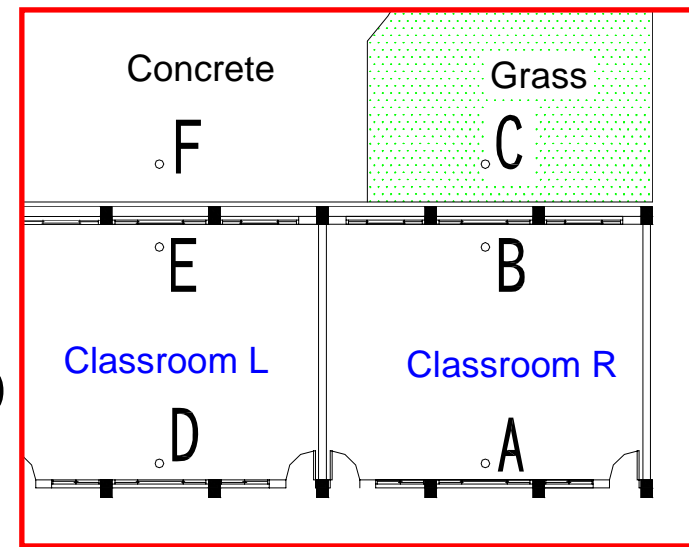
# Thermal Comfort Indices

- Both the PMV and SET\* shows: E>B>A>D

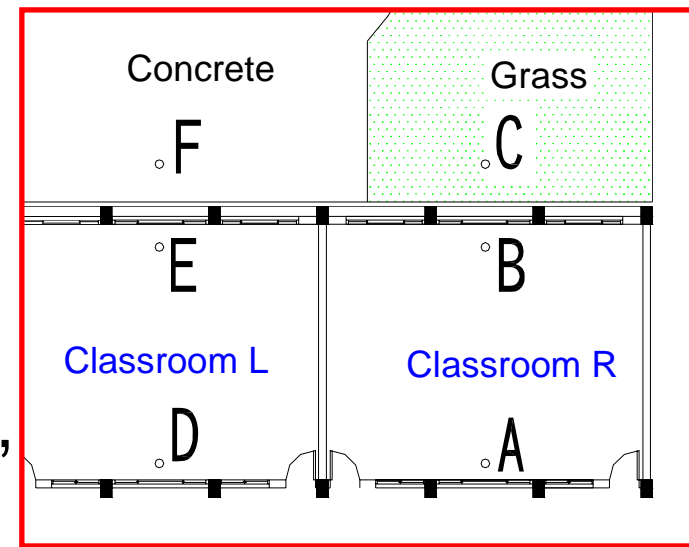


# Subjective thermal evaluation

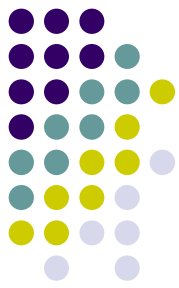
- Most occupants of points B feel more comfortable than those in D
- However, point D have higher MRT, SET\*, PMV than B



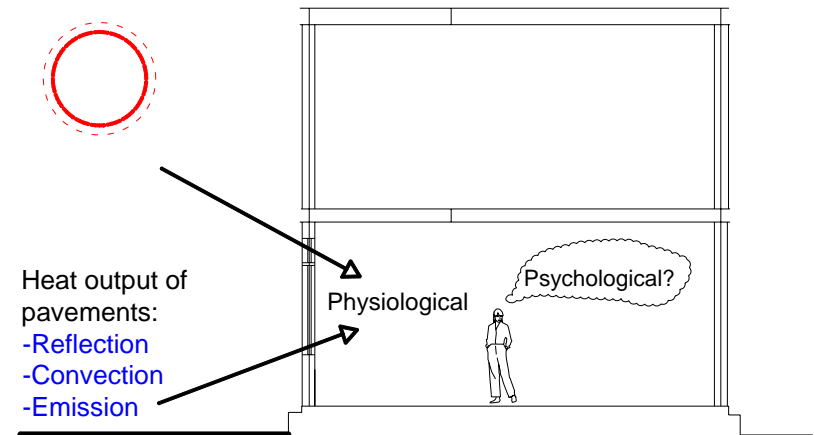
- Although the objective thermal environment of D is better than B, People in point B subjectively feel more comfortable than D



# Why different?

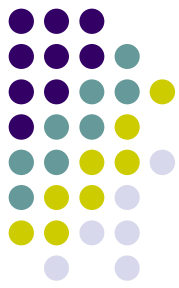


- Occupants thermal sensations affected by ..
  - physiological factor
  - and psychological factor

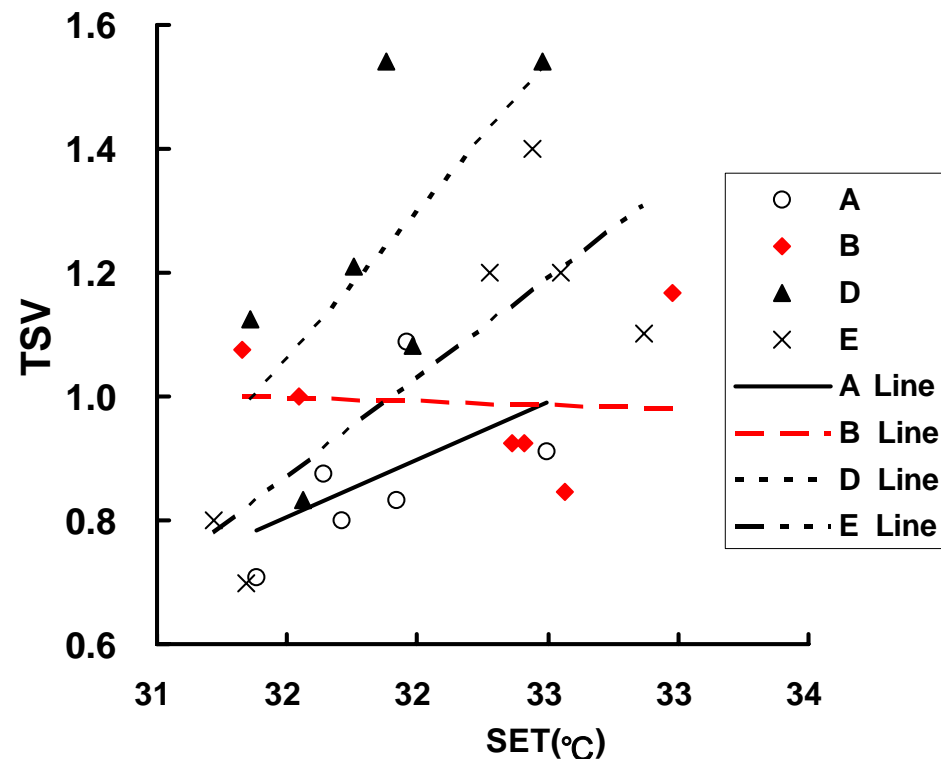


- Locations with grass outside may make people feel thermal environment more comfortable than locations with artificial pavement outside
  - even when both locations share identical thermal indices.

# Correlation Analysis

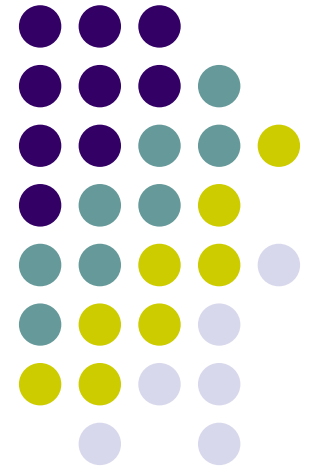


- Subjective thermal evaluation for point B is not entirely determined by SET\*
- External ground greenery helps maintain stable physiological and psychological thermal comfort.



# 4. CONCLUSION

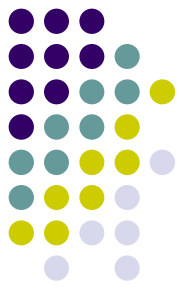
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- 1. Classrooms with **concrete** outside had higher indoor temperatures than those with **grass** outside.
- 2. Occupants felt more comfortable in classrooms with greenery outside than in those with concrete outside.
- 3. The material outside classrooms both **physiologically** and **psychologically** affects the indoor thermal environment, and classrooms with grass outside offer occupants a more **stable** and **comfortable** environment.

# Thank you



- Please also send your commend to
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