# 650: Evaluating psychological effects of climatic factors in educational environments

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**Abstract**

Human comfort in educational environments may be effected by a wide range of climatic conditions, including air temperature, relative humidity, air movement, solar radiation, air quality, etc. and also human-corresponding factors like activity, clothing level, age and so on. In this paper in relation to educational environments, various design representations and different climatic conditions are investigated in Tabriz, Iran, in order to estimate how climatic condition affects people. The research is based on both multidisciplinary and interdisciplinary strategies including three disciplines: architecture, climatology and psychology. It also deals with the relative effects of air temperature, relative humidity and air movement as well as with the relationship between thermal sensation and overall comfort sensation, as are found in educational indoor comfort studies. The paper has common case studies carried out in the classes of a university, including measurements of meteorological variables, interviews and observation of human activity at each location. Multiple regression analysis of meteorological and behavioral data showed that air temperature, relative humidity have a more significant influence than air movement on people's assessment of place perceptions and place-related attendance. In this context, perceived choice over a source of discomfort is another important parameter for people in indoor spaces.

Keywords: educational spaces, indoor environment climatic condition, environmental psychology, thermal comfort

## 1. Introduction

Scientists from a wide range of different disciplines including architecture, climatology, and psychology have long been interested in how weather and climate affect people's behaviors and they tend to define suitable climatic condition in different environments. Some researchers that have evaluated effects of climatic factors in urban spaces [6,9,21,22,29,30] and also researches in indoor climatic condition show the significance of this study. In this article, several factors have been taken to influence people's perceptions and use of indoor environments, among them the design and function of spaces, as well as the physiological and psychological parameters involved in human reactions to the physical environment. To date, most of the researches have been carried out within the individual disciplines. As a result, the different factors have been identified, but knowledge of their individual and combined influence is still lacking, since an integrated research approach is necessary for such analyses.

### 1.1 The purpose of this paper

This paper describes an investigation of indoor public places in relation to micrometeorological variations and human perceptions of climate. The study combines meteorological and behavioral data in an analysis of the impact of three climate variables (air temperature (T), relative humidity (RH), and air movement (AM)) on participants' perceptions of current internal micro-climate and their behavioral, aesthetical and emotional assessments of two indoor public spaces at the university. The main goal of the investigation was to test the hypothesis that air temperature and relative humidity, the two climatic factors, have a more significant influence than air movement on peoples' internal micro-climate assessments and place-related perceptions, emotions and attendance.

## 2. Methodology

### 2.1 An integrated research approach

The present study is part of the "indoor educational climatic conditions" project, involving scientists from the fields of climatology, psychology and architecture. The project has an integrated research approach with a common goal: its aim is to traverse disciplinary boundaries in order to develop integrated knowledge and theory, i.e., to conduct interdisciplinary work [33] for the purposes of analyzing the complex relational links between climate and human behavior and its implications for sustainable design [12,13,15,16,18,31].

### 2.2 Case studies

Case studies were conducted in the city of Tabriz, which is located at latitude 38°N on west part of Iran. Two indoor public spaces with different designs and varying climatic conditions like a theory class and a design atelier were included in the study(Fig. 1). Micrometeorological measurements, observations and structured interviews were conducted simultaneously during these case studies (May 2008). Each study period included five days over a period of two weeks. The aim was to find 5 days in each location with different external climate, with respect to air temperature, relative humidity and air movement. Totally, 20 days of measurements, observations and interviews were conducted in Tabriz. The case studies were performed in the morning between 10 to 11 a.m. and in the evening between 4 to 5 p.m. Temperature and humidity normally reach their daily maxima during this period, and the places under study are frequently used by people.

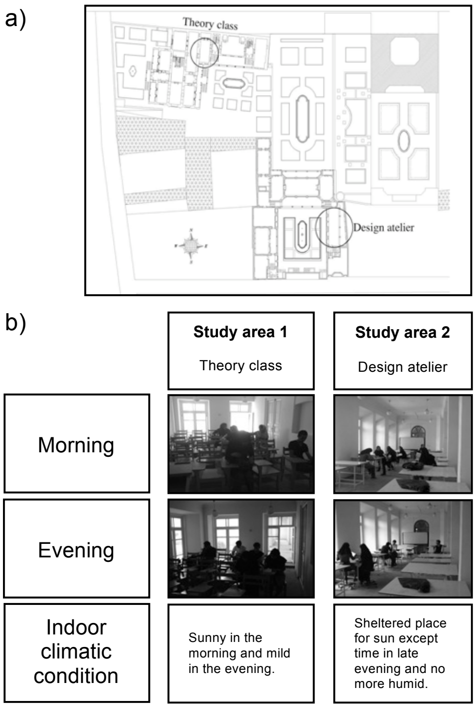


*Fig 1. a)An architecture faculty site-plan in Tabriz b) Photographs of the two study areas and the characteristics of the indoor climate at each place.*

### 2.3 Micrometeorological measurements

The air temperature and relative humidity as well as air movement were measured at a height of 1.1 m above the ground, corresponding to the average height of the center of gravity for adults [20]. The instruments were installed on two carriers. One carrier was always situated at the center of the case study, while the other was moved daily between the three other study areas. The final results in a specific time have been the average amount of these measurements. The air movement is the item has been considered in this study. Generally, high values of air movement (e.g. > 1 m/s) result in inconvenient conditions, while lower values represent more suitable conditions. The air movement in indoor spaces has a low value and most of the time is not noticeable, but however, it affects people’s perceptions, emotions and place-related attendance.

### 2.4 Observations and structured interviews

Observations of human activity and behavior were made every 20 min, at the same time as the meteorological measurements and interviews. Physical activity, i.e., the number of people sitting, standing and walking as well as visible qualifications such as talking and reading were observed.

The structured interview contained eight main questions about demographic variables, clothing, general and specific questions about current internal micro-climate, behavior, feelings and attitudes related to the site [31]. People were randomly approached and the questionnaire took about five minutes to be completed. A total number of 60 people participated in the study (20 at the theory class and 40 at the design atelier corresponding to area size) that is about 20% percent of people in the faculty. There were similar numbers of women and men visiting each place. About 80% of the participants were between 20 and 25 years old. Three main measures of dependency, that are, three questions from the questionnaire were analyzed in this study. These concerned the estimations of current internal micro-climate and the behavioral and perceptual dimensions of a place. The first question was related to the current internal micro-climate perception. Participants were asked to respond to three 5-point scales ranging from 1 to 5: (1) calm–windy, (2) cold–warm and (3) good–bad for indoor activity [15,31]. The second question was related to the place perception. Participants were asked to respond according to four 5-point scales ranging from 1 to 5: (1) ugly–beautiful,(2) unpleasant–pleasant,(3) windy–calm and (4) cold–warm [15,31]. The third question was related to the emotional states of (de)activation and (dis)pleasure and place sensation. Participants had to respond according to four 5-point scales ranging from 1 to 5: (1) elated–bored, (2) glad–gloomy, (3) calm–nervous, and (4) active–passive. These scales were derived from the Knez and Hygge (2001) measure of the current effect. In connection to the last question, participants were also asked to estimate their thermal comfort by responding according to a 9-point scale ranging from very cold to very hot, with the score 5 indicating “comfortable” [19].

### 2.5 Multiple regression analyses

Multiple regression analyses were performed to investigate the influence of the three independent physical variables (Air temperature (T); relative humidity (RH); Air movement (AM)) on the participants’ evaluations of current internal micro-climate and their behavioral and perceptual estimations of each place (the dependent variables i.e. the three above-mentioned questions from the questionnaire). This statistical technique may be viewed as a descriptive or inferential instrument by which the (linear) influence of the three independent variables on each dependent variable evaluated collectively and separately. In other words, the amount of variance in a dependent variable (criterion) that could be attributed to the three independent variables (predictors) jointly and separately was analyzed. The analysis is based on 1-min mean data for the air temperature, relative humidity measured at each site and 5-min mean data for the air movement due to its high variability. The meteorological data were synchronized to the start time of each interview. It must be noted that 10-min mean data for Air temperature were also analyzed; however there was no difference between these results and those obtained using the 5-min mean data. In order to determine whether the independent variables correlated, i.e., to check for multicollinearity, the variance inflation factor (VIF) was calculated. Multicollinearity would result in a greater error variance in the multiple regression models and is considered to be severe when VIF is greater than 10 [26]. However, the results of the multiple regression analyses described below showed VIFs < 3 indicating a very low (and for the multiple regression models, satisfactory) level of Intercorrelation between the independent variables.

## 3. Climate and educational environments design

There are some of the researches that investigate environmental comfort such as thermal analysis or relative humidity in educational buildings [3,11]. Climatic study of educational environments with real occupation levels in different conditions is presented in these studies. After validation, the numerical model is used to evaluate the occupants' comfort levels in several spaces. The evaluation of the building's thermal response and air quality in different conditions, using the detailed analysis of devices effects and mean value of thermal comfort level for students and professors in different classrooms, are the main objective points of these works. The projects presented enables us to suggest some improvements in design of these constructions to obtain buildings with better thermal comfort and air quality levels for occupants and with low energy consumption levels. The thermal analysis in indoor conditions is extremely important because most of the school activities occur in these spaces. The air movement rate inside an occupied compartment, which influences the air movement quality level, can be calculated using different recommendations and methodologies presented in national and international standards [24]. In the mentioned works the standards [1] that define a limit for an air movement rate for each occupant and this specific kind of space is used. Thus, It has been used from the results and experiences of these studies in different parts of present research.

## 4. Climate and human psychology

Research on how emotion, cognition and activity influence the tolerance range for climate comfort is comparatively rare. The relation between functional use and microclimatic conditions has been confirmed by several studies [7,23,31,32,34,35] which show that comfortable external climate conditions, i.e., high temperature and access to sunlight increases the number of people present in one place. Studies also show that both too cold and too warm conditions have a negative influence on the emotional state, which in turn tends to trigger aggressive behavior [5,28]. The researches suggest that emotional states can influence cognitive processes [2,17]. If climate is a moderator of emotional state, then it is likely that it also affects other aspects of the environmental experience, such as the visual aesthetics [8,15]. There also appears to be a relation between thermal comfort and some psychological aspects of the environmental experience [15].

The concept of space, comprising physical and spatial connotations, has traditionally been used in geographical and architectural discourse. It does not include the psychological and social aspects of spatial experiences and has therefore been redefined in environmental psychology by the notion of place [10]. Several authors have sketched similar accounts of the theory of a place [4] comprising three key components: physical (form and space), functional (activities) and psychological (meanings people assign to a place) aspects. Canter (1997) has further developed his earlier model into four "facets" of place: functional differentiation, place objectives, scale of interaction and aspects of design. Place objectives extend the previous psychological (individual) aspects by including both social and cultural components, while the scale of interaction addresses the environmental aspects. Yet, as pointed out by Knez (2005), an insufficiency in these theoretical accounts is the omission of climate, which influences individual, social, economic [25], and criminal behavior [27] and memories of, and meanings we attribute to places [13].

## 5. Results

The results are reported and discussed with a focus on both of the two spaces. Results from the multiple regression analyses are presented in Tables 1-6 for each place and dependent variable (question from the questionnaire). Due to the huge amount of statistical data involved, only significant results are written and discussed.

### 5.1 Meteorological statistics

The city of Tabriz is located in highland climate region and has a mean air temperature of 26°C in July and -1.7 °C in January (Fig. 2a). Fig. 2a shows the range around the min, mean, max daytime air temperature value, gained and measured form synoptic station in Tabriz while Fig. 2b shows outdoor air temperature, relative-humidity and air movement during measurement. Since the mechanical air condition systems have been removed in both case studies and some fenestrations have been opened during a)

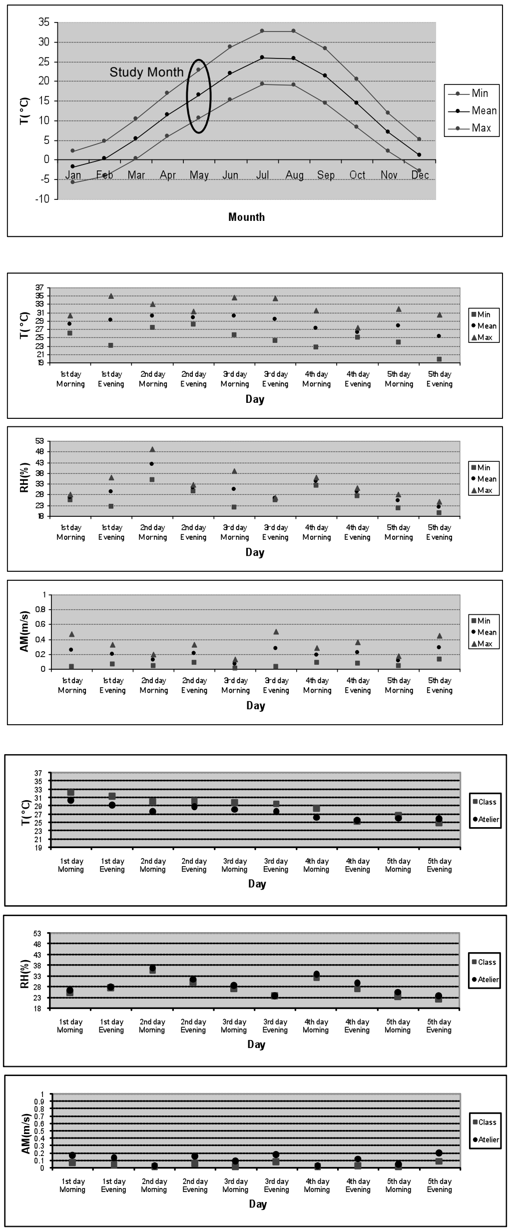


Fig 2. a) Monthly mean air temperature and mean daily minimum and maximum temperature in Tabriz. (55 years average rate,1951-2005, 5th June 2008, Synoptic station, Tabriz, Iran, http://www.weather.ir/)
b)The daily air Temperature (T), relative humidity(RH) and air movement(AM) during the morning and evening measurements.
c)The daily air Temperature (T), relative humidity(RH) and air movement(AM) during the morning and evening measurements in class and atelier.

summer, so, the Variations of external climate during the study is reflected in the range of studied items at the two places and there isn't much difference between external climate and internal micro-climate(Fig. 2b and 2c). The mean daytime air temperatures during the case studies in the evening were low in comparison to the morning. In fact, the coldest event in one day since the beginning of the experiment (19.8°C) occurred during the evening measurements. The mean daytime air temperature during the experiment taken in the morning was higher than the 55-year mean value outside (Fig. 2). The morning case study covers wider range of relative humidity, followed by the evening case study with slightly lower humidity. In addition, the morning and evening case studies included more days with near normal air temperature (Fig. 2).

The mean air movement was much higher at the design atelier in comparison to the theory class, especially in the evening. Sometimes the air movement at the design atelier was almost as high as the outside. This was probably due to large area of the atelier and its large fenestrations.

The largest variation in air movement occurred during the evening case study (Fig. 2b). But it should be mentioned that in the both morning and evening, the air movement variation was relatively small in both case studies. The air movement values shown in Fig. 2b are generally below 0.5 m/s and are often less than 0.3 m/s, which may appear to be low values. However, it must be remembered that the air movement values in Fig. 2b were measured at a height of 1.1 m above ground and in outdoor spaces at the university.

### 5.2 Results from study area 1: the theory class

It is notable that the air temperature during the morning case study is only slightly higher than during the evening case studies which is an effect of the extra warmth of the sun in the morning. However, measurements at the theory class show somewhat higher temperatures, especially during morning case study because of the windows toward the southern light.

#### 5.2.1 Internal micro-climate perception

The results of the multiple regression analysis showed that the number of people who are comfortable for doing educational activity in the theory class decreased with increasing air temperature ($\beta$ = -.43) and decreasing relative humidity ($\beta$ = 0.4) and air movement ($\beta$ = 0.16), with $R^2$ = 0.12 (see Table 1). Technically, $\beta$ shows the direction and strength of the slope between Y and X and $R^2$ indicates how much of the variance in Y is explained by X.

The results also show that the air temperature and the relative humidity had a significant influence on the participants' assessments of the current internal micro-climate on the "cold–warm" dimensions. More precisely, the current internal micro-climate was estimated as warmer at lower air movements and higher air temperatures , and 23% of the variance. The current internal micro-climate was estimated as calmer when the air movement decreased, indicating a relatively low $R^2$ value of 0.14. In addition, participants estimated internal micro-climate as being better for indoor activity at times with normal relative humidity (35%), low air temperature and increasing air movement ($R^2$ = 0.12).

Table 1: Results from multiple regression analyses (N = 20) on the influence of air temperature (T=24.9 to

32.3°C), relative humidity (RH=22.1–35.7%), air movement (AM =0.01–0.09m/s) on the perceived “current internal micro-climate” in the class during whole day

| Statistic data | | Internal micro-climate perception | | | | | |
|---|---|---|---|---|---|---|---|
| | | Calm-Windy | | Cold-warm | | Good-bad for indoor activity | |
| | | $R^2$ | β | $R^2$ | β | $R^2$ | β |
| Independent variable | T | | .17 | | -.84 | | -.43 |
| | RH | .14 | .16 | .23 | -.52 | .12 | .4 |
| | AM | | -.29 | | .19 | | .16 |

### 5.2.2 Place perception

Results showed that the participants perceived the class to be more beautiful at times with high air movement and low air temperatures, indicating a low $R^2$ value of 0.11 (see Table 2).

As shown in Table 2, the class was also rated as being more pleasant when the relative humidity increased. The results also show that the participants estimated this place as being more calm and warm at times with low air movement, normal relative humidity and higher air temperature.

Table 2: Results from multiple regression analyses (N = 20) on the influence of air temperature (T=24.9 to 32.3°C), relative humidity (RH=22.1–35.7%), air movement (AM =0.01–0.09m/s) on the perceived “place right now” in the class during whole day

| Statistic data | | Place perception | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | ugly–beautiful | | not pleasant–pleasant | | windy–calm | | cold–warm | |
| | | $R^2$ | β | $R^2$ | β | $R^2$ | β | $R^2$ | β |
| Independent variable | T | | .51 | | .32 | | -.09 | | -.66 |
| | RH | .11 | -.25 | .06 | -.16 | .1 | -.27 | .18 | -.28 |
| | AM | | -.1 | | -.13 | | .3 | | .08 |

### 5.2.3 Place sensation

As shown in Table 3, the participants felt more positive (that is, more elated, happier, calmer) in the class at lower air temperatures. In addition, they felt more elated on occasions with higher relative humidity and more psychologically comfortable at higher air movements.

## 5.3 Results from study area 2: the design atelier

Contrary to what is generally observed in class, the atelier is measured with higher air-temperature in the evening due to the windows toward the west and higher air movement. So it was gained quite different results in the morning and evening according to internal micro-climate alterations.

Table 3: Results from multiple regression analyses (N = 20) on the influence of air temperature (T=24.9 to 32.3°C), relative humidity (RH=22.1–35.7%), air movement (AM =0.01–0.09m/s) on the total attendance and perceived “feelings right now” in the class during whole day

| Statistic data | | Place sensation | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | elated–bored | | glad–gloomy | | calm–nervous | | active–passive | |
| | | $R^2$ | β | $R^2$ | β | $R^2$ | β | $R^2$ | β |
| Independent variable | T | | -.53 | | -.42 | | -.31 | | -.35 |
| | RH | .05 | .29 | .07 | .23 | .09 | .17 | .15 | .36 |
| | AM | | .22 | | .17 | | .11 | | .13 |

### 5.3.1 Internal micro-climate perception

The results showed that the total assessment at the design atelier increased when the air temperature decreased and the air movement increased, accounting for almost 30% of the variance (see Table 4).The results also showed that the participants perceived the current internal micro-climate to be better for indoor activity when the air temperature decrease. The current internal micro-climate, on the other hand, was perceived as being colder at higher air movements, lower air temperature and relative humidity, accounting for 11% of the variance. Participants assessed the internal micro-climate as being windier at higher air movements. However, the analysis also showed that “windy internal micro-climate” can be related to a decrease in air temperature, which is probably a local, place-related phenomenon. It was also observed that normal relative humidity (about 30%) was perceived to be important for indoor activity.

Table 4: Results from multiple regression analyses (N = 40) on the influence of air temperature (T=25.4 to 30.2°C), relative humidity (RH=23.5–36.5%), air movement (AM =0.02–0.19m/s) on the perceived “current internal micro-climate” in the atelier during whole day

| Statistic data | | Internal micro-climate perception | | | | | |
|---|---|---|---|---|---|---|---|
| | | Calm-Windy | | Cold-warm | | Good-bad for indoor activity | |
| | | $R^2$ | β | $R^2$ | β | $R^2$ | β |
| Independent variable | T | | .11 | | -.61 | | -.36 |
| | RH | .24 | .15 | .11 | -.26 | .29 | .43 |
| | AM | | -.32 | | .13 | | .23 |

### 5.3.2 Place perception

The results showed that the participants rated the atelier as being more beautiful at lower air temperatures and higher air movements (see Table 5). The atelier was also assessed as being a more pleasant place when the air movement and relative humidity increased.

Table 5: Results from multiple regression analyses (N = 40) on the influence of air temperature (T=25.4 to 30.2°C), relative humidity (RH=23.5–36.5%), air movement (AM =0.02–0.19m/s) on the perceived “place right now” in the atelier during whole day

| Statistic data | Place perception | | | |
|---|---|---|---|---|
| | ugly– | not | windy– | cold– |

| | | beautiful | | pleasant–pleasant | | calm | | warm | |
|---|---|---|---|---|---|---|---|---|---|
| | | $R^2$ | β | $R^2$ | β | $R^2$ | β | $R^2$ | β |
| Independent variable | T | .27 | .46 | .2 | .32 | .23 | -.07 | .16 | -.49 |
| | RH | | -.17 | | -.23 | | -.3 | | -.37 |
| | AM | | -.15 | | -.19 | | .41 | | .09 |

The participants assessed the atelier as being a calmer place when the air movement decreased, but higher air temperatures also turned out to have a little influence on the participants' assessment of this place's "windiness".

### 5.3.3 Place sensation

As shown in Table 6, the participants felt happier and calmer at higher air movements at the atelier. The results also showed that they felt more active at the atelier during conditions with higher relative humidity and air movement.

Table 6: Results from multiple regression analyses (N = 30) on the influence of air temperature (T=25.4 to 40.2°C), relative humidity (RH=23.5–36.5%), air movement (AM =0.02–0.19m/s) on the perceived "feelings right now" in the atelier during whole day

| Statistic data | | Place sensation | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | elated–bored | | glad–gloomy | | calm–nervous | | active–passive | |
| | | $R^2$ | β | $R^2$ | β | $R^2$ | β | $R^2$ | β |
| Independent variable | T | .13 | -.42 | .09 | -.31 | .06 | -.24 | .21 | -.47 |
| | RH | | .39 | | .28 | | .22 | | .42 |
| | AM | | .16 | | .2 | | .12 | | .15 |

## 6. Discussion

In general, the results of this study confirm the hypothesis that the air temperature, relative humidity have a more significant influence than air movement on the participants' internal micro-climate assessments and place-related perceptions, emotions and attendance. The results clearly show that indoor climatic condition have a significant influence on two (functional and psychological) of three components constituting a place (Fig. 3).

### 6.1 Internal micro-climate parameters and the functional component

Regarding the functional component of a place, measured as the participants' evaluation, the air temperature was shown to have a similarly significant influence in all places. Fig. 4 gives a schematic illustration of this impact (reported in-

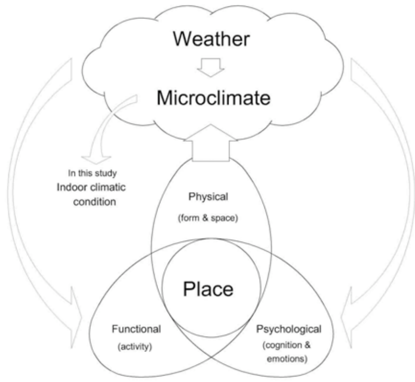


*Fig 3. The complex interrelation between weather and internal micro-climate and the three components of place, adapted from Canter (1977).*

Tables 1 and 6). It is clear from the diagrams in Fig. 4 that when the air temperature rose, the evaluation of visitors highly increased in both places. The statistical analysis showed that about 50% of the slope in total assessment could be explained by air temperature.

Another general result for both places was that the participants classified normal relative humidity and internal micro-climate with relatively high air movements as being better for indoor activity.

### 6.2 Internal micro-climate parameters and the psychological component

It is known that architects and climatologists have long argued that climate-related issues are

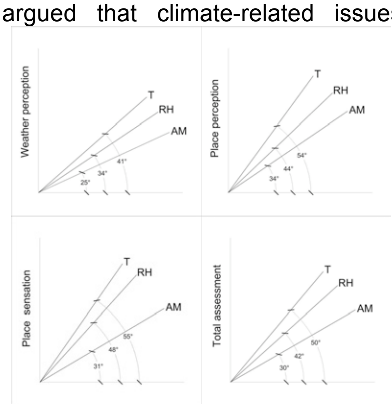


*Fig 4. Plots of total result and three main questions as function of air temperature, relative humidity and air movement in both places. The diagrams are a Schematic illustration of the statistics reported in tables 1-6*

important for life. It is very clear from the study that the people visiting the both places do care about, and are influenced by, the internal micro-climate. Thus, internal micro-climate parameters are important—not only did they influence the number of people who used the spaces, but they also influenced how people assessed the places and how being in these places made them feel, i.e., the psychological component of a place.

Concerning the psychologically-related results, and as pointed out in Section 5, it must be noted that only tentative links between participants' behavior, internal micro-climate and place were indicated, due to the low $R^2$ values. This type of result is related to measurement errors in subjective assessment and to some of uncontrolled variables that may also have had an impact on participants' psychological responses. An interesting result is that the open, wide area of atelier was estimated to be more beautiful as a result of high air movement and low air temperatures, as shown in Table 5. Participants also felt more active when there was higher air movement in the atelier (Table 6).

The results also show that relative humidity also highly influenced the subjective weather-related assessments of warmth in class (see Table 1).

### 6.3 Internal micro-climate parameters and the physical component

Internal micro-climate influence the physical component of a place. However, as observed in both case studies, the relationships also work in the opposite direction. A building's shape, orientation, material, color and etc. influence temperature, air movement and other parameters to produce an indoor-specific weather condition. Designers are thus able to create different kind of environments that take advantage of the positive effects of the existing internal micro-climate. Climate design has always been a natural part of local and traditional buildings. However, when designing the modern one, the designer has to consider many different convicting aspects. Thus climate-related issues have a relatively small impact on the planning process. We hope, however, that studies such as this one will serve to support the arguments in favor of using climate-sensitive planning in future designs of cities. Viewed together with results illustrating the influence of internal micro-climate parameters on perceptions and emotions, it is clear that climate-sensitive planning can be an important tool in the drive to increase sustainability in the educational environment. It is important to remember that climate-sensitive planning of every different kind of places is important, regardless of which future direction is chosen.

## 7. Conclusion

Internal micro-climate parameters like air temperature and relative humidity have a more significant influence than air movement on participants' internal micro-climate assessments and place-related perceptions, emotions, attendance. It is, thus, clear that air temperature and relative humidity are vital aspects of the functional and psychological components of a place.

The results support the arguments in favor of employing climate-sensitive planning in future educational environments design and planning projects, as the physical component of a place that can be designed to influence the indoor specific climatic condition and consequently people's place-related attendance, perceptions and emotions.

## 8. Acknowledgements

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