An Evaluation of the Educational Effectiveness of Using the Bioclimatic Chart in a Design Exercise

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ABSTRACT: The results of a content analysis of design drawings for a simple shelter, produced in response to a bioclimatic design class, are examined to investigate the influence that the use of the bioclimatic chart has on the work of student architects. The sample studied came from seventy first-year students of architecture who were divided into groups to produce designs for five regions with contrasting climates. The paper also identifies those aspects of bioclimatic design that appear to have presented problems for this cohort of students, and concludes with recommendations for improving the pedagogical value of the exercise.

Conference Topic 9: Education and technology transfer

Keywords: bioclimatic chart, bioclimatic design, educational exercise, pedagogical evaluation, design information.

INTRODUCTION

For several decades it has been assumed that the bioclimatic chart can help architects produce more climate-responsive designs. This paper tests this assumption using the results of an analysis of student work produced in a design exercise carried out by first year students. The project brief requires the design of a small building, such as a kiosk or shelter for bus passengers, requiring no more than two enclosed, or partially enclosed, zones.

The introduction to the project includes three lectures that explain the project requirements and introduce the principles of bio-climatic design, with reference to textbooks such as [1] and [2]. A two-hour workshop session is also provided, serving small groups of about 12 students, and covering the components of thermal comfort, the selection and analysis of climatic data, and experience of plotting data on the bio-climatic chart. Students are then given two weeks to complete the design, in parallel with work on a different studio design project and regular lecture courses. The project brief includes an explicit instruction to concentrate on demonstrating a design response to the climate information provided, and not to cultural, or other site-specific information. The sites are selected with the intention of being unfamiliar to the students.

2. PROJECT BRIEF

Students are given climatic data defining the range of mean relative humidity and mean ambient temperature for the four months representing the solstice and equinox periods. The data is provided in numeric tables. They are instructed to respond in three stages:

(i) Plotting - to represent the climatic data on a bioclimatic chart
(ii) Diagnosis - to present their interpretation of the bioclimatic chart representation, by listing the design strategies that can improve human comfort in their allotted climate, in the form of a diagnosis for each season
(iii) Visualisation - to present drawings that communicate the design of the shelter specified in the project brief. They were also asked to illustrate the effect of noon solar altitude angles on the exposure of any openings on the equatorial-facing side of their shelter.

These stages require students to both combine and transform the data provided. They must associate temperature and humidity information and transfer the abstract numeric format into an analogical chart format to assist in data interpretation. They then need to translate the results of this exercise into an abstract textual list – the diagnosis. Finally they must respond to both their diagnosis, and the functional requirements of the design brief by creating iconic images (drawings) of a 3-D form with specified materials and surface finishes. These steps deliberately reflect key stages of the design process identified in the seminal icon design process model [3], intended to assist in understanding the process of utilising technical information within the architectural design process.

2.1 Plotting Climate Data

The process of representing the climate data on a bio-climatic chart has been clearly explained by Docherty and Szokolay [4]. The chart is based on the concept introduced by Olgyay [5]. The chart used in the exercise analysed in this paper is in the form of the psychrometric chart, proposed by Givoni [6]. More
specifically, the students in this exercise used a chart based on one produced by Yannas [7], which in turn was derived from [6], [8] and [9]. It provides an overlay of design strategies related to different zones of the chart, to assist in the diagnosis process.

2.2 Diagnosis
The chart used in this exercise proposes 12 potential design strategies, or control responses, which might improve human comfort. The number of strategies appropriate to a region varies greatly. In Belem, Brazil, only 3 strategies are suggested as being useful. In Kashgar, China, on the other hand, the climate presents a greater variety of conditions across the seasons, and 6 strategies are indicated as appropriate. An example of a diagnosis is presented in figure 1. In the climates covered in the exercise analysed, 8 of the 13 potential strategies were relevant.

<table>
<thead>
<tr>
<th>Winter:</th>
<th>Heat with Fuel all day</th>
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<tbody>
<tr>
<td>Spring:</td>
<td>Heat with Fuel early &amp; late</td>
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<tr>
<td></td>
<td>Reduce Heat Loss</td>
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<td></td>
<td>Exploit Heat Gains</td>
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<td></td>
<td>Passive Solar Heating</td>
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<tr>
<td>Summer:</td>
<td>Reduce Heat Loss early &amp; late in the day</td>
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<tr>
<td></td>
<td>Promote Natural Ventilation</td>
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<tr>
<td></td>
<td>Night Cooling with Thermal Mass</td>
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<td></td>
<td>Shading Most of the Daytime</td>
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<tr>
<td>Autumn:</td>
<td>Reduce Heat Loss early &amp; late in the day</td>
</tr>
<tr>
<td></td>
<td>Promote Natural Ventilation</td>
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<td></td>
<td>Night Cooling w. Thermal Mass</td>
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<td></td>
<td>Shading Most of the Daytime</td>
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**Figure 1:** Sample of a Diagnosis of design strategies required to improve comfort in Kashgar, China.

2.3 Visualisation
In addition to plotting data on the chart and diagnosing appropriate strategies for each season, students are required to submit A3 sheets showing a three-dimensional image of their design (figure 3), a cross-section illustrating interaction of the shelter with climatic components (figure 2), and a solar angle study for noon on the equator-facing fenestration/opening. This provides the material that has been used in this paper as evidence of visualisation of appropriate design responses.

3. PILOT STUDY
A pilot study on the work of 10 students from earlier years was carried out to help define the graphic indicators to be used in the content analysis. Examples of the type of drawings analysed are shown in figure 2 and 3, and an analysis of the variety and proportional adoption of different graphic formats used by students to translate bioclimatic diagnosis into design is shown in figure 4.
4. CONTENT ANALYSIS OF STUDENT DESIGNS

The graphic content analysis of work from a cohort of 70 students responding to climate data from 5 sites was based on checklists for both diagnosis and visualisation of appropriate strategies for each climate. These were used to record the proportion of strategies correctly diagnosed and visualised by students. The accuracy of their bioclimatic chart plotting was also recorded.

5. RESULTS

5.1 Plotting Results

94% of students were able to plot accurately on the chart the climate data supplied to them in numeric tables (figure 4). The most common plotting error was the combination maximum (daytime) temperature with maximum (night-time) relative humidity.

Most of the errors recorded were from the group of students responding to the climate of Alice Springs. This location has a high diurnal swing in relative humidity, and it is possible that this led to more detectable errors in their work.

5.1 Diagnosis and Visualisation Results

The proportion of correct responses in diagnosis and in visualisation of appropriate design strategies is illustrated in Figure 5. In visualising a design solution, 2/3 or more students included appropriate strategies, with the exception of two strategies. This provides evidence of the students’ ability to translate strategies from the abstract text of their diagnosis, to the richer form of representation in the design drawings. The two strategies with which the majority of students demonstrated problems, in both diagnosis and visualisation, were evaporative cooling, and night cooling of thermal mass.

There is a close correlation between the scores for diagnosis and visualisation of most design strategies. This is of particular significance as it supports the underlying pedagogic assumption that the development of propositions based on an analysis of climatic data using the bioclimatic chart does relate to the appearance of graphic indicators of appropriate bioclimatic responses in the design drawings.

There were two strategies which did not demonstrate a close match between the scores for correct responses in the diagnosis and the visualisation, and there are credible explanations for both these deviations.

There was a much higher score for visualisation (96%) of shading compared with its diagnosis (67%). This might be explained by the content of project brief, which specifically required the presentation of a drawing showing the relationship between the shelter and the solar altitude angles. There may also be a perceptual problem in that the requirement for a shading diagnosis is represented on the chart in a slightly different way than the other strategies. (It is indicated graphically by the crossing of a line, rather than by occupation of a zone on the chart).

For the strategy of “dehumidification” 67% of students correctly visualised it, compared with only 36% who correctly diagnosed it. However this apparently large difference is caused by only 3 students, due to the atypical small sample of just 9 students assigned to the only climate in which dehumidification was a requirement.
6. SUMMARY OF RESULTS

6.1 Accuracy of plotting
94% of students plotted numeric climatic data with sufficient accuracy to facilitate a correct diagnosis.

6.2 Visualisation correlates with Diagnosis
There is a close correlation, for the majority of design strategies, between the scores for diagnosis and visualisation. This supports the underlying pedagogic assumption that the correct use of the bioclimatic chart can positively influence design.

6.3 Problem strategies for students
More than half of the students failed to respond adequately to the need for evaporative cooling and night cooling of thermal mass, both in diagnosis and visualisation.

6.4 Anecdotal evidence
Design assessors made the following observations:
(a) Many students experience difficulty in correctly relating solar altitude angles to their buildings in a useful way
(b) Many students, who correctly calculate and represent solar altitude angles, nonetheless ignore the fact that their windows are exposed to sunshine when the bio-climatic chart indicates a need for shading.
(c) One of the most common design errors is excessive use of glazing contravening required strategies for minimising heat loss, and for shading.

CONCLUSIONS

The high scores for accuracy of data plotting, and the correlation between appropriate design strategies in both diagnosis and visualisation lend support to the proposition that the bioclimatic chart offers effective support in designing buildings for climates known only through abstract climatic statistics.

The results indicate that the diagnosis of appropriate design strategies might be improved through clearer representation of the design strategies in relation to zones on the chart, particularly with regard to the need for shading.

In the preparatory lectures and workshops, this group of students would have benefited from a greater emphasis on the hazards associated with large areas of glazing in many climatic conditions, the means of evaluating the performance of shading devices, and increased familiarisation with the strategies of evaporative cooling and night cooling of thermal mass.

REFERENCES