AN APPROACH TO TEACHING CALCULATION PROCEDURES FOR PASSIVE DESIGN

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ABSTRACT

This paper describes the development, testing and revision of a workbook, "Design Procedures for Daylighting, Passive Solar Heating and Cooling", which emphasizes the integration of a set of calculation procedures with the building design process. The work was carried out in the University of Oregon Department of Architecture in 1980-81 and funded through the U.S.D.O.E. Passive Solar Curriculum Development project, administered by the University of Pennsylvania.

1. INTRODUCTION

Inherent in the nature of passive design and the goal of conserving energy is the use of the building and site, rather than separate mechanical systems, to keep people comfortable. To achieve this, early building design decisions about organization and form must recognize these goals. Similarly, the problem boundaries must include off-site and site-scale decisions, as well as those involved in making pieces of the building. The dynamic aspects of seasonal change are resolved in the building design rather than solved by relying on concentrated energy forms.

It is clear that changing the content but not the methods of the traditional mechanical systems classes in which calculations are learned, isolated from architectural problems, will not encourage students to address these issues. The handbook of procedures which we have developed is an approach to the integration of these. It is organized both by subject areas (heating, cooling, lighting) and by phases of the design process (conceptualizing, scheming, developing, finalizing) (see Fig. 1), so it can be used in either a lecture course or the design process. In either mode, one building/site design is carried through the workbook, providing a consistent architectural context for the procedures. The building/site program includes an internally-dominated-load piece and a skin-dominated-load piece.

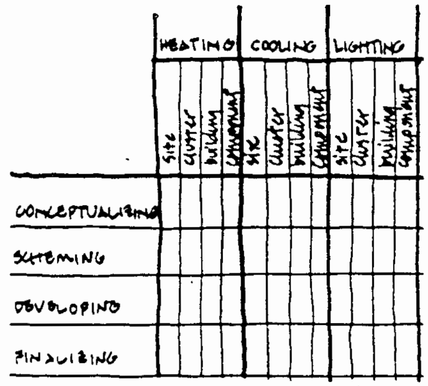

Fig. 1 - Structure of the Workbook

Climate is viewed as the context in which you design; you begin by analyzing it to set the stage for design. Within each subject such as heating are the four design phases. Within each phase is a sequence of steps: a goal is stated, design strategies are presented, and a design is asked for. A set of evaluation procedures is used to see if the design meets a set of criteria, and, if not, the student redesigns.

We have expanded our definition of calculation procedures to include organizational attitudes, rules of thumb and graphic techniques as well as numerical calculations. We have also identified three major procedure types: design strategies, analysis tools and evaluation tools, which are used in the process described above.

2. TESTING THE WORKBOOK

We have been developing and testing this workbook for several years at the University of Oregon. The draft of the current form was tested during the 1980-81 school year by 275 architecture students enrolled in the Environmental Controls Systems (ECS) course sequence. In response to feedback from the students, teaching assistants, and professionals in the field, we have made a number of revisions. As described below, these changes clarify the original intentions of the workbook while essentially maintaining the structure and content which was tested.

3. FEEDBACK AND REVISIONS

3.1 Flexibility in Subject Order

The ECS course used to test the workbook is a large lecture class. In a lecture format course it is easiest to relate the course work to a vertical subject area like passive heating and deal with it from general to specific and then move on to the next subject area, as in Fig. 2.

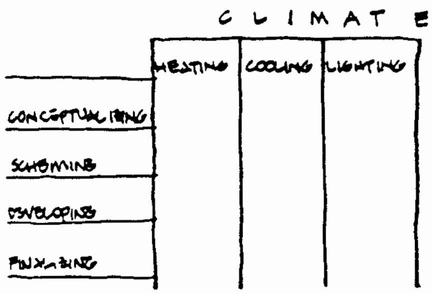

Fig. 2. Organization for Lecture Format

The student teams were assigned to work with four climatically different locations: Phoenix, Arizona; Dodge City, Kansas; Charleston, South Carolina; and Madison, Wisconsin. These cities represent typical climate regions in the U.S.: hot-arid, temperate, hot-humid, and cool. Those teams who saw cooling as their major concern were disturbed by doing the heating exercise first. Although we may continue to teach heating first, we did revise the exercises so they are not sequential and can be worked in any order desired once the climate analysis has been completed.

3.2 The Building-Site

Throughout the exercises the students design a small factory and associated office/conference building, and related outside spaces. Beyond the obvious use differences, these two buildings are very different in the amount of internal heat they generate and lighting levels they require. Designing them consistently through the workbook allows students to really understand conceptually the differences between an Internally Dominated Load (IDL) building and a Skin Dominated Load (SDL) building and to propose and evaluate design responses in which the forms and massing of the buildings provided exciting comparisons.

3.3 Climate as Context

A major tenet of the workbook is that many ECS decisions are strongly climate related. Therefore, we have treated climate as the context within which the heating, cooling, and lighting problems are defined.

Working with four climates offers an opportunity for comparison, which keeps the students much more interested in basic analysis procedures as well as making the broad applicability of the procedures more obvious.

We have termed the calculation procedures used to understand this context Analysis Tools. They characterize important variables within particular climates and set the stage for understanding the importance of heating, cooling, and daylighting.

Analysis procedures which establish daylighting potential and need have been added. This way the potential of daylighting as a major formal influence can be understood, as are thermal considerations, before the first design proposal is made.

We have also refined a set of charts which use skin-to-volume ratios and internal gains to understand the SDL/IDL nature of the program. The new charts estimate, very roughly, the temperature at which the building is supplying its own heat. Looking at the relation of this "balance point" temperature and the outside temperature forms a strong understanding of the building in a dynamic rather than static environment.

3.4 Design Phases

The vertical axis in Fig. 1 identifies steps in the design process. The specific number of steps is less important than the idea that different kinds of information are needed at each stage of the process and that these steps occur across all subject areas.

We have defined the phases by looking at the nature of the decisions at each step. Conceptualizing concerns itself with ways of thinking about building. Decisions at this point are frequently independent of (or very selective in terms of) program and context. Calculation procedures associated with this design stage concentrate on providing ways of thinking about the subject areas, which are compatible with a range of starting points and are powerful in their organization of ideas. Scheming calculation procedures concentrate on revealing major context and form relationships in the project (for example, orientation, shape and size). These calculation procedures are presented in a form which is generative, that is, one which aids in the development of design concepts. Developing procedures are presented in a way which encourages the comparison of whole systems (such as M. Millet's graphic method of daylight analysis, which allows comparison of daylight factor contours that result from different window sizes and location). Finalizing techniques allow detailed comparison of system performance and sizing.

It is important to realize that we are interested in these as phases in the building design process, and not as system design. As a clear example you can do a schematic design of a plumbing system, but that would not be part of what you did in the schematic building design phase. We discovered that as the building itself was used rather than conventional systems, as in passive heating, we had not been careful to define the steps in decision making which would correspond to our description of the design phases.

In the revision we clarified the sequence and design impact of the decisions made within each exercise. The workbook is now organized in such a way that the information is usable whether access is horizontal or vertical. In the design process the subject areas are most likely linked together and divided horizontally according to design phase, as in Fig. 3.

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Clarity of design phases, like the independence of subject order, also means that the workbook can be added to and rearranged to meet specific needs. Although it addresses passive heating and cooling and daylighting specifically, it leads into conventional HVAC and electric lighting, and these exercises could be easily added. We currently use additional exercises in water/waste and acoustics.

3.5 Iterative Design Process

Because one intent of the workbook is to let students understand how calculation procedures can work for them in design, it was not only important to move through recognizable design phases but also to reinforce the reiterative process of design-evaluate-redesign-reevaluate. This means simultaneously being clear about when you are designing and when you are evaluating and making it easy and comfortable to go back through.

Within each design phase, such as scheming, the same steps are followed. Goals are stated which tell you where you are going with the design, and a set of given Criteria to meet then tell you when you've arrived. We have made this explicit in the revision because we found that the most successful parts of the draft were those in which students knew they had achieved something, whether this was a goal such as providing sufficient daylighting or knowing if the building was warm enough in January.

The Design Strategies presented next concentrate on changing the building design to meet ECS objectives. Because general building design objectives are much broader than ECS objectives, it is important to present redundant design strategies. Any of several avenues then may be used to approach an ECS design objective. The more ways there are to manipulate the building design to meet the ECS objectives, the better chance there is that ECS objectives will be included.

These strategies are presented for multiple scales: site, cluster, building and component. These scales are not meant to imply sizes but scale relationships. Problems may be solved at one scale or at several. For example, in the summer, the building cluster might provide shade for an outside court in the morning and afternoon when the sun is low, and the court could have an awning (component scale) to be shaded from the high sun at mid-day.

The design strategies were a very popular part of the exercises because students are presented with design ideas as part of using calculation procedures. We are also able to present time as a dimension of design, for example shifting use patterns instead of increasing openings for cooling, reemphasizing architecture and buildings as dynamic rather than static.

The students use any, all, or none of the design strategies in the Design step, presenting a design proposition that they think will achieve the goals. They then Evaluate these designs. Calculation procedures we have called Evaluation Tools are used to see if the ECS objectives have been met. These are generally those thought of as "calculation procedures" although we have included rules of thumb and graphic evaluations as well as numerical sizing. The nature of the design process demands that evaluation tools for preliminary design stages be extremely easy and fast to use.

There are increasing degrees of both time consumption and accuracy as one moves through the design phase. In response to student feedback, we have matched each criterion with specific evaluation tools that tell you whether you have met that criterion.

In addition to requiring the designs to meet the criteria in order to overcome the hesitancy to redesign and reevaluate we found among the students, we provide two sets of answer blanks throughout the evaluation tools labeled "1st Trial" and "2nd Trial" designs. At the end of each evaluation section we ask "Does your first trial design meet the criteria? If not, what will you change for your second trial?"

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We have included as an appendix a worked example of all the exercises for Salem, OR. The students value this section highly, partly for the convenience of finding an explanation at 3 a.m., and also because it indicates that we aren't trying to keep secrets from them but rather we're trying to make something that, although complicated, is useful to them.

4. CONCLUSION

Even with the revisions described above we would still expect a preliminary resistance on the part of the students to the harder work involved in integrating energy and design and to the breaking of their streotypes about the relation between design and mechanical systems.

Throughout the course, however, they become involved with the ideas and problems presented and personally involved with and committed to their designs. Questions in our lecture class were of significantly higher quality than previous years, and we have a preliminary indication that some of this information might be seeping its way into studio and onto the drawing boards. That's what it's all about.

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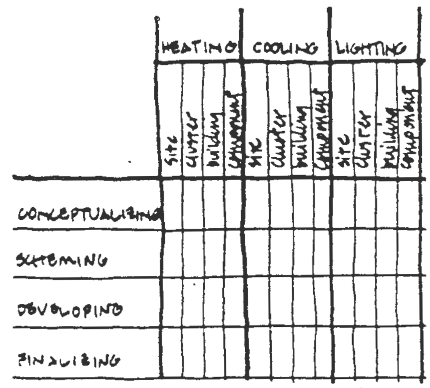

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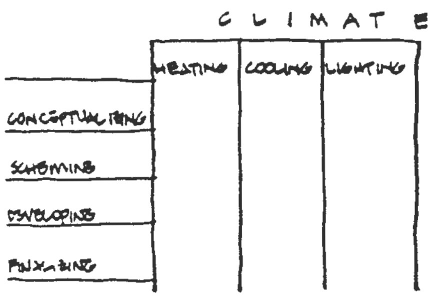

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