within one session. Such conditions are, of course, highly artificial so we must be careful how we analyse the findings of such studies.

Not surprisingly, most design strategies seem to begin with a brief scanning of the problem as it appears initially. However, it is also common to find that elements of solutions rather than problems begin to emerge very early on in the process. In one of the earliest of these studies, subjects were asked to design a new bathroom, and they invariably began drawing solutions almost immediately (Eastman 1970). One experimental technique used to externalise and reveal design thinking is to use groups of subjects and record their conversations. One such study of architectural students designing a nursery school was video-recorded and then analysed for both words and actions. It was rarely very long in these protocols before the subjects began to use such phrases as 'this suggests' or 'we could try'. It was found here that different aspects of the problem were examined to see what they might suggest in terms of ideas about the solution, rather than analysed in their own right (Agabani 1980).

There are many ways of analysing the data from such design process protocols. A notable contribution to the field has been made by a conference at which all the contributors had analysed the same two video-recorded design protocols. Both were industrial design problems, in one case tackled by an individual who was asked to think aloud and in the other case was worked on by a group (Cross, Christiaans et al. 1996). Some researchers tried to break down the process into sequences, others looked to classify the kinds of cognitive activity they thought to be revealed. Others still tried to link the events on the path to the solution with phases of thinking, while yet others concentrated on the cognitive style of the designers. Finally, researchers concentrated on the inadequacies of the protocols themselves to properly represent real design activity (Lloyd, Lawson et al. 1995). Thus there was sufficient material here to publish a book larger than this one just on two design protocols!

## Heuristic strategies

An examination of protocols obtained from such closely observed design sessions reveals that most designers adopt strategies which are heuristic in nature. The essence of this approach is that it is simultaneously educational and solution seeking. Heuristic strategies

do not so much rely upon theoretical first principles as on experience and rules of thumb.

To illustrate this principle let us look at two methods of sizing timber floor joists. In the first, theoretical method, calculations are performed using the known compressive and bending stress capabilities and elasticity of the timber. The calculations give a depth of timber which will not deflect more than 0.003 of the span and will not cause the bending and sheer stresses to exceed the permitted levels. The calculations are based on established theories of structural mechanics and would be performed by structural engineers and required for building regulation approval. The alternative to this precise but laborious procedure is to use our second, rule of thumb or heuristic, method. There are many possible rules such as 'the depth of 50 mm wide joists at 400 mm centres is 25 mm for every half metre of span'. Such a method is by no means precise but will never be very far out. However, not only does the method go straight to the solution, but it is educational in the sense of clearly identifying the critical relationship between depth and span of the joist. The rule of thumb is also much more practical in that timber does not come in an infinite range of depths but is commonly available in multiples of 25 mm.

This rule of thumb provides a good model of the heuristic strategy so commonly employed by designers. A rough idea is quickly developed for the most significant elements of the solution which can then be checked by more precise methods and adjusted as necessary. Such rules as those relating depth and span clearly cover the critical aspect of the problem of sizing a joist. However, in more complex design situations it is by no means so easy to decide what is critical. Indeed what is important or critical is likely to be a matter of opinion. Here designers need rather more sophisticated heuristic strategies.

## Three early phases of working on the same problem

To see how this might actually work in practice we shall briefly consider the approach taken by three groups of architecture students towards a competition to design a large new county authority office building. After a fairly short period of work the groups presented their ideas and thoughts so far. Here, then, rather than working on protocols we can analyse the presentations made by the design students at an early interim criticism session with their tutors.