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Spatial Visualization Research Survey

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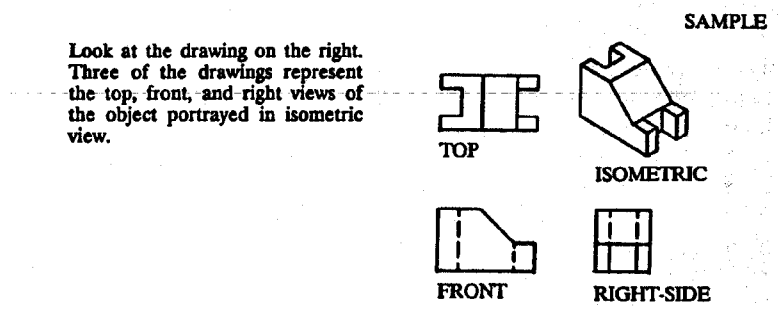
Introduction

This research investigates the differences in the way beginning students and experienced instructors visualize and solve orthogonal projection problems requiring the creation of an axonometric sketch for certain object. This type of spatial visualization problem requires the mental manipulation of two-dimensional visual information about an object and its transformation into a three-dimensional description of the object projected onto a plane.

Methodology

Over 500 students and instructors, from the USA and Europe, participated in the spatial visualization research survey. The survey consisted of a questionnaire with an example and two sets of third-angle multiviews of a three-dimensional object in isometric (see Figure 1). The participants were requested to solve the problems using their own method. Solutions were scored to measure sketching ability, drawing mechanics, conceptual quality and correctness. In addition, participants were asked to provide their age, experience and to describe the method and time required to solve the problems.

Research Participants: Participants in the project were 349 students taking an introductory course in engineering graphics, and 161 instructors with experience teaching engineering graphics. The students ranged from 18 to 36 years of age, and reported an average of 0.8 years of experience creating or interpreting technical drawings of three-dimensional objects (generally in high-school drafting courses). The instructors ranged between 21 and 84 years of age, and reported an average of 24.4 years of relevant experience. There were no significant ($p < .05$) relations between age and any of the dependent measures in either age group and thus all results are collapsed over this variable in subsequent analyses.



Now look at the two sets of drawings below. For each would you please: (a) sketch the object (i.e., isometric drawing illustrating the top, front, and right sides); and (b) indicate how many minutes you spend on each drawing.

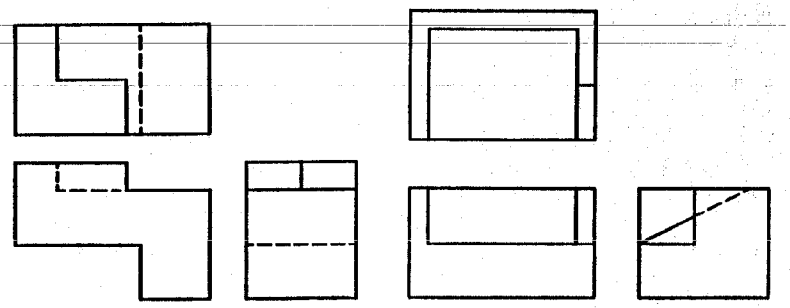


Fig. 1 Questionnaire's Sample Drawing & Problems.

Procedure: All participants were requested to complete the brief questionnaire administered in the classroom for students, and sent by mail to instructors. A total of 400 questionnaires were mailed. As mentioned earlier, two of the items in the questionnaire consisted of three orthographic views. The third item in the questionnaire asked for a description of the procedure followed in visualizing the three-dimensional objects drawn in the previous problems. In order to suggest plausible alternatives, three possible strategies were briefly described. These consisted of: (a) creating an outline box and then projecting each view on the appropriate surface; (b) folding the top and right surfaces around the front; and (c) imagining viewing the object from different vantage points. The fourth question asked whether, when visualizing three-dimensional objects from two-dimensional views, the respondent has the feeling that he or she knows what the object is going to look like before sketching it, or whether logical analysis and sketching is necessary to determine how it will look. The final item in the questionnaire solicited recommendations about the best way of learning to visualize three-dimensional objects from orthographic drawings.

Results

The two drawings and the responses to the third and fourth questions in the questionnaire were independently evaluated by two experienced graduate teaching assistants in an engineering graphics course. Drawings were rated on dimensions of conceptual quality, reflecting the degree to which the sketch resembled the correct or appropriate object, with all important surfaces, edges, etc., and mechanical quality, indicating the accuracy of line positioning, precision of surface placement, edge alignment, etc. Each dimension was separately evaluated on a 5-point scale with larger ratings representing higher quality. The correlations between the ratings of the two evaluators were relatively high, .79 for conceptual quality and .78 for mechanical quality, and therefore the average of the two ratings was used in all subsequent analyses.

Figure 2 illustrates, for both students and instructors, the mean ratings for conceptual quality and mechanical quality, and the mean number of minutes reported for each problem. As would be expected from the composition of the groups, the instructors produced drawings of higher quality, and took less time to do so, than did the students. The lines above each bar, indicating 95% confidence intervals, reveal that all of these differences were highly reliable.

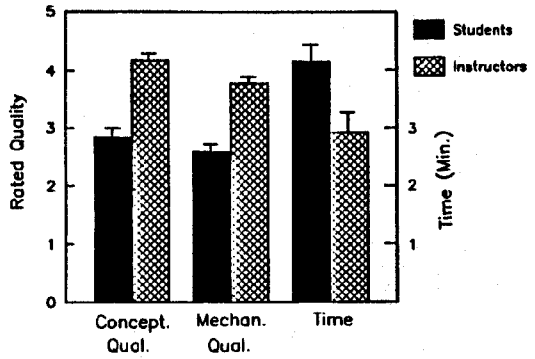


Fig. 2 Conceptual and mechanical quality and time reported for each problem.

Many students and a few instructors failed to respond to the item requesting information about the strategy used when visualizing objects. Furthermore, some of the responses, particularly those from students, were difficult to classify (as evident in lack of agreement between the two evaluators). However, reliable categorization of the responses into one of three types of strategies was possible for 109 students and 121 instructors. The percentages of each group reporting each type of strategy are displayed in Figure 3. Notice that a larger percentage of instructors than students indicated that they used the outline box method, while more students than instructors reported using the different vantage point method. Both of these differences were significant; outline box, $z = 5.98$, $p < .01$, vantage points, $z = 4.86$, $p < .01$. The two groups did not differ significantly in the percentage of respondents reporting that they used the folding method, $z = 1.61$, $p > .05$.

The two evaluators agreed on the classification of responses to the question concerning whether the respondents knew what the object would look like before sketching it on 118 of the available student responses and on 155 of the available instructor responses. The percentages of each group reporting that they knew what the object would look like, or that logical analysis and sketching was required, are displayed in Figure 4. The percentage of instructors reporting that they knew what the object would look like before sketching it was significantly greater ($z = 4.13$, $p < .01$) than the percentage of students reporting knowing what the object would look like. Conversely, the percentage of students was significantly greater than the percentage of instructors in reporting that logical analysis was required to determine the identity of the object.

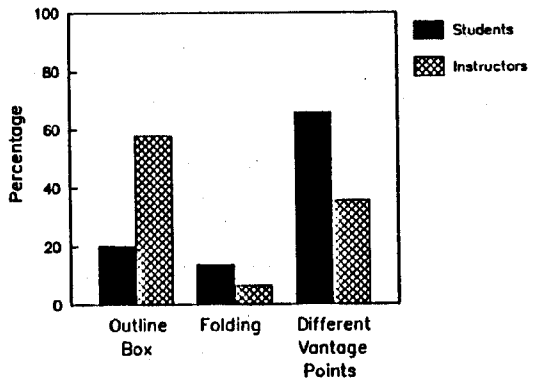


Fig. 3 Percentages of each group reporting for each type of strategy.

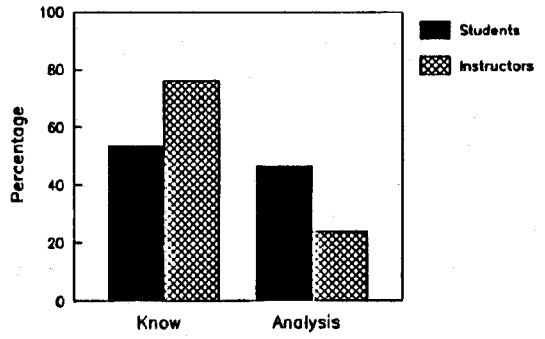


Fig. 4 Report on "they know what the object looks like" or used logical analysis.

One final analysis was conducted to determine if there were any significant relations between the measures of drawing time or quality and the reported solution strategies. Analyses of variance revealed differences as a function of solution method (i.e., outline box, folding, different vantage points) in either conceptual quality, mechanical quality, or drawing time for either students or instructors. However, students reporting that they knew what the object would look like before sketching it had higher ratings of conceptual quality (3.55 vs. 2.72, $F[1,97] = 22.62$, $p < .01$), and of mechanical quality (3.14 vs. 2.35, $F[1,97] = 23.58$, $p < .01$) than did students reporting that logical analysis and sketching was necessary. Among the instructors, those reporting that they knew what the object would look like took less time to draw the sketches (2.65 vs.

3.65 minutes, $F[1,131] = 6.89$, $p < .01$) than those reporting that logical analysis and sketching was necessary before knowing what the object would look like.

Conclusions and Recommendations

The main findings of this study can be summarized as follows:

(1) The performance of the experienced and inexperienced groups were measured as well as the age-related trends and it was found that there were no significant relations between age and any of the dependent measures in either age group.

(2) Instructors favor outline box method while students prefer different vantage points method.

(3) A large percentage of instructors report that they know what the object will look like before actually constructing the drawing, but much smaller percentage for students.

(4) It was rather surprising that no drawing quality differences were found in either group as a function of the type of strategy used.

(5) As expected, students required more time to solve the problems.

(6) Most of the strategies reported were successfully used by instructors and students to visualize and sketch isometrics from the given projections.

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