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# Schema Acquisition and Solution Strategy in Statistics Problem Solving

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## Introduction

Research on multistep problem solving in knowledge-rich domains, such as physics and mathematics, has revealed several differences between experts and novices. Experts tend to classify problems according to abstract principles useful for their solution (Chi, Feltovich, & Glaser, 1981) and solve problems using a forward-working strategy (Simon & Simon, 1978), whereas novices tend to classify problems based on surface features and solve problems using a backwards-chained strategy. To explain these findings it is generally posited that experts possess domain-specific knowledge in the form of schemas. However, schemas are theoretical constructs inferred from the phenomena they are used to explain. It is proposed here that empirically derived knowledge representations using the Pathfinder scaling algorithm can provide a more direct observation of schema acquisition associated with the attainment of expertise. Pathfinder operates on proximity data to provide a network representation with the most efficient connections between concepts, and has been used as a valid assessment of classroom learning (Schvaneveldt, 1990).

## Methods

Twenty-eight students enrolled at UNM served as participants. They were asked to think aloud as they solved 17 statistics word problems (13 training, 4 test problems). All could be solved using the following equations:  $df_B = a - 1$ ,  $MS_B = SS_B / df_B$ ,  $F = MS_B / MS_W$ . Participants' solutions and verbal protocols were recorded. After solving all problems, participants rated the relatedness of all pairwise combinations of the six concepts contained in the equations above.

## Results and Discussion

Problem solutions were analyzed to determine the strategy used on each of the test problems, and relatedness ratings were submitted to Pathfinder to derive visual representations of participant's acquired knowledge structures.

In all of the problems, participants were given two of the following values and asked to solve for the other:  $a$ ,  $MS_B$ ,  $SS_B$ . Thus, all problems could be solved by first calculating  $df_B$  and then calculating the goal value. A schema useful for solving these problems, then, would involve the relationships between  $df_B$  and each of  $a$ ,  $MS_B$ , and  $SS_B$ . This "df schema" can be seen in the knowledge structures as links between those concepts (see Figure 1). Participant's knowledge structures were analyzed for the presence of this schema.

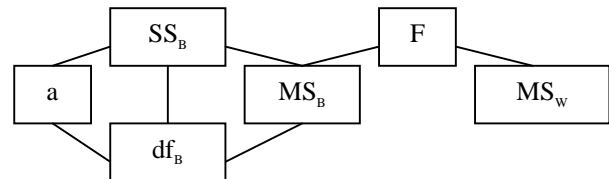


Figure 1: Sample knowledge representation

If schemas defined in this manner are associated with expert-like problem solution, then participants that possess the  $df$  schema should be more likely to solve problems in a forward manner. A solution was considered forward if the subgoal ( $df_B$ ) was calculated before consideration of an equation containing the goal; otherwise it was considered backward. Overall, ten participants solved all of the test problems using a forward strategy. Seven of these ten possessed the schema. Of seven participants, on the other hand, who solved one or fewer test problems using a forward strategy, only one possessed the schema. This discrepancy is found to be significant by a Fisher's exact test,  $p=.05$ .

In the final test problem, participants were given values for  $MS_W$ ,  $F$  in addition to  $a$ ,  $SS_B$  and asked to find  $MS_B$  (Note that participants were not trained on this type problem). Thus, they could use the forward solution described above, or they could work backwards using the equation  $F = MS_B / MS_W$  to solve for the goal in one step. It was hypothesized that participants possessing the  $df$  schema would use the former strategy while those that did not would use the latter. Nine of 13 participants possessing the  $df$  schema did solve the final problem using the forward strategy, while only three of 15 participants that did not possess the schema did so. This discrepancy is also significant,  $p=.02$ .

These results show that Pathfinder derived representations can reveal the acquisition of schemas that guide expert-like solution of statistics problems. In the absence of these schemas, problem solvers tend to rely on backwards-chained strategies, as predicted.

## References

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