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ABSTRACT

The objectives of this study centered on ability of first-grade students in seriate learning, the strategies used, the effects of the seriation variable on task performance, and the effects of the number of objects used. Students from four randomly selected schools were asked to order a set of 4, 6, 8, or 10 objects on length or weight. The sequence in which objects were placed in the row and the actual ranks of the objects in the final row was recorded. A 4 x 2 x 4 random block design was used. The Task Score (TS) was the Kendall Tau coefficient between the child's ranking of the object and the correct ranking. Three other scores were devised to distinguish strategies. Extreme Value Selecters (EVS) identified extent of value among unordered objects. Rearrangers (RAR) made an unordered row and then rearranged the objects until correct. Students in the Insertion Strategy group (INS) randomly selected an unordered object and inserted it in the ordered row. The most important finding was that successful performance on the seriation task was usually achieved with use of a relatively systematic strategy. It appeared that most of the students in the population had yet to master seriation with weight. (Author/EB)

STRATEGIES USED BY FIRST-GRADE CHILDREN IN ORDERING OBJECTS BY WEIGHT AND LENGTH

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Goals of science education such as improving problem solving ability, developing skills with science processes, and facilitating future acquisition of scientific information all imply an expectation of transfer of learning. Bessemer and Smith have argued that the design of instruction to facilitate transfer of learning should take into account the nature of the conceptual networks involved, the tasks to be performed, and the information processing strategies by which important tasks might be carried out. (Bessemer and Smith, 1972; Smith, 1974). They propose that instructional objectives be expressed in terms of these three dimensions and that research on instruction be conducted within this framework. In terms of this framework, the present study examined the strategies used by first-grade children to perform an ordering task using conceptual networks related to the quantitative perceptual variables length and weight. Although the study contributes directly to existing knowledge of seriation, it has broader implications in that it exhibits a systematic approach to the study of transfer of learning.

THEORETICAL BACKGROUND

As Shulman and Tamir have pointed out, the contrasting position of Gagne, Bruner, and Ausubel on what kinds of knowledge should be taught "are all rooted in their contrasting views of the psychology of transfer of learning" (1973, p.). This statement communicates two important observations. First, there is agreement on the importance of transfer of learning. Second, there is disagreement on how transfer might best be achieved.

The Concept-Task-Strategy (CTS) model proposed by Bessemer and Smith is not a psychological theory of transfer as such. Rather, it represents an eclectic position with regard to transfer by calling for description of objectives in terms of features relevant to several potential mechanisms of transfer. The model can be considered a component of educational theory which addresses the question, how should educational objectives be expressed? Thus, it provides a descriptive framework within which to conduct systematic research to assess the relative contributions of each mechanism of transfer and the conditions under which the alternative mechanisms function.

One potential mechanism of transfer which can be examined within the CTS model is based on information processing strategies for performing tasks, that is, on the third dimension of the model. This mechanism assumes that the learner can acquire a strategy for performing a given task. Such a strategy could then facilitate performance of the task with new conceptual networks. Further, the strategy might function as a subroutine in strategies for more complex tasks thus facilitating performance on those tasks. Note that the expected scope of such transfer is limited by the type of conceptual networks to which the tasks and strategies are relevant. A detailed rationale for pursuing this potential mechanism is presented by Bessemer and Smith (1972).

The strategies might be formulated as production systems as described by Newell and Simon (1972). Procuction system models of weight seriation by children were published by Baylor and Gascon (1974) while the present study was being carried out. Klahr and Wallace (1970) used flow chart models to represent strategies for some Piagetian classification tasks. The components of the flow chart represent primary processing steps or sequences of such steps. These are defined in terms of relevant psychological constructs. McClain and Smith (1972)describe how such an approach might be employed within the CTS model. Flow chart models of this sort were used in the analysis generating the present study.

RELATED RESEARCH

A major contribution to the literature on the ordering task is the Piagetian research on the development of the seriation cognitive structures. These structures form an integral part of the developments referred to collectively as concrete operations (Inhelder and Piaget, 1969). The major findings of this research are that ability to order on the basis of length develops in most children by the age of 5-7 (Ibid.), while the ability to order on weight usually follows 1-2 years later (Piaget and Inhelder, 1941).

An offshoot of the Piagetian research involved attempts to advance children's seriation stage placement through instruction (Coxford, 1964; Schafer, 1971). Although these efforts had varying degrees of success, the generalization seems warranted that it is difficult to accelerate development through short term instruction on selected tasks.

As pointed out by Voelker (1974), most of the studies performed in a Piagetian framework are asking questions about development per se. The orientation of the present line of inquiry is consistent with the recommendation of Voelker that science educators utilize the Piagetian research to derive implications of development for the learning of science in school. Our questions concern the science concepts, tasks and strategies which children at a given Piagetian level of development can learn.

Few studies of the ordering task have dealt explicitly with how the child performs the task. Investigation of the strategy mechanism of transfer referred to above requires just such a focus. An exception is the work of Baylor and Gascon (1974) on weight seriation which came to our attention after the present study was planned and underway. Their work represents a rigorous application of the methods proposed by Newell and Simon (1972). Baylor and Gascon found that children 6-12 tend to use one of two base strategies (and infrequently a third) for ordering objects by weight using a balance for comparisons. These base strategies are essentially identical to those we identified in our pilot work. They are described in a later section.

THE RESEARCH PROBLEM

The context of the present study can be described in terms of a task x content matrix (Table 1). The task and conceptual networks involved in this study are indicated in the matrix. The conceptual networks relate to quantitative perceptual variables such as length, weight, texture, pitch and so on (Table 2). The tasks (Table 3) are relevant to any such network.

The task x content context for the study was selected for the following reasons:

1) The quantitative variable is one of the most pervasive types of construct in science.
2) Preliminary analysis of strategies for discovering relations between variables suggests that an important component of such strategies is ordering on a single variable.
3) Considerable data has been collected by researchers investigating this task, especially with length.
4) Mastery of the ordering task with a number of quantitative perceptual variables represents objectives of many existing elementary curricula.

Our pilot work indicated that most children of first-grade age tend to employ one of two basic strategies* for ordering objects on length and weight. The Extreme Value Selection (EVS) strategy involves repeated selection of the unordered object with the greatest value on the ordering variable and placement of that object next (at the end of the row). The Insertion (INS) strategy involves repeated random selection of an unordered object and insertion into the ordered row wherever it belongs. The major features of these strategies are contrasted in Table 4. A third basic strategy is also listed. The rearrangement (RAR) strategy involves the construction of an incorrectly (or approximately) ordered row followed by rearrangements to produce a correct row. This strategy was not observed in our pilot work with children although we had observed the RAR strategy with adults. Since a small number of instances of the RAR strategy was found in the study, it is included here. As mentioned above, a study of weight seriation (Baylor and Gascon, 1974), published as our study was getting underway, reported finding similar strategies for children aged 6-12.

Because of our expectation that most children would tend to use the EVS or INS strategies, the present study was designed to determine the frequency of use of these strategies and the extent to which the children adhered to our models of them. We were further interested in determining the extent to which the nature of the task environment influenced the strategy used. We chose to vary the ordering variable (length or weight) and the number of objects ordered. Since we used sets of objects which differed on only one variable, the actual objects differed as well as the variable itself.

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* The term basic strategy is employed here because a number of alternative forms of these strategies might be distinguised but are not for the purposes of the present study.

TABLE 1

TASK-CONTENT MATRIX FOR CONCEPTUAL NETWORKS
INVOLVING QUANTITATIVE PERCEPTUAL VARIABLES

Task	Content (Conceptual Network)				
	Length	Weight	Texture	Force	Pitch etc.
Element Selection					
Insertion					
Seriation					
Mult. Seriation					
etc.					

TABLE 2

COMPONENTS OF CONCEPTUAL NETWORKS
FOR QUANTITATIVE PERCEPTUAL VARIABLES

Component	Conceptual Networks			
	Length	Weight	Texture	Force
Variable Name	length	weight	texture	force
Values	longer longest shorter shortest	heavier heaviest lighter lightest	rougher roughest smoother smoothest	harder to pull hardest to pull easier to pull easiest to pull
Observation Procedure	juxta-position visual scanning	hefting (kinesthetic perception)	rubbing with fingers (tactile perception)	pulling (kinesthetic perception)
Elements	Discrete physical objects			

TABLE 3

DEFINITIONS OF TASKS FOR
QUANTITATIVE PERCEPTUAL VARIABLES

Task	Definition	Example
Element Selection		
	Given: A set of elements A value	Given: A set of sedimentary rocks roughest
	Required: the element(s) described by the given value	Required: the rock with the roughest texture
Insertion		
	Given: An ordered subset	Given: A subset of springs ordered on the compression force required
	An unordered element(s)	An unordered spring
	The name of the ordering variable	How hard it is to push
	Required: the set of elements ordered on the named variable	Required: the set of springs ordered on the compression force required
Seriation		
	Given: A set of elements A variable name An observation procedure	Given: A set of cylinders Volume Displacement of water
	Required: The set of elements ordered on the named variable	Required: The cylinders ordered on volume
Multiple Seriation		
	Given: A set of elements Two variable names	Given: A set of igneous rocks Grain size and proportion of light-colored grains
	Required: The set of elements ordered on both variables	Required: The rocks ordered by grain size and proprotion of light-colored grains

TABLE 4

DISTINCTIVE FEATURES OF
ALTERNATIVE SERIATION STRATEGIES

Feature	Strategy		
	Extreme Value Selection (EVS)	Insertion (INS)	Rearrangement (RAR)
Selection of objects to place	extreme value	random	not usually the extreme value
Correctness of partial row	correct	correct	not correct (or approximate)
Position of placement into row	sequentially side to side	random	open
Rearrangements	none	none	many ($\frac{n}{3}$ where n is the number of objects)

TABLE 5

EXPERIMENTAL DESIGN FOR INVESTIGATING
EFFECTS OF SERIATION VARIABLE, AND
NUMBER OF SCHOOL OBJECTS BLOCKING
ON (4 x 2 x 4 Generalized Randomized Block)

Seriation Variable	No. of Objects	School (Block) A	B	C	D	Total
Length	4	n = 3	3	3	3	12
	6	3	3	3	3	12
	8	3	3	3	3	12
	10	3	3	3	3	12
Subtotal		12	12	12	12	48
Weight	4	3	3	3	3	12
	6	3	3	3	3	12
	8	3	3	3	3	12
	10	3	3	3	3	12
Subtotal		12	12	12	12	48
Total	24	24	24	24	24	96

Earlier studies had indicated that not all children of first-grade age could perform the ordering task correctly. A secondary purpose of the study was to determine how accurately the children performed the task and the effects of the ordering variable and number of objects on their accuracy.

Thus, the study was designed to answer the following questions:

1) How accurate are first-grade children in perceptually ordering objects on length and weight?
2) Does the ordering variable (length or weight) affect their accuracy?
3) Does the number of objects (4, 6, 8 or 10) affect their accuracy?
4) To what extent do first-grade children employ the EVS, INS or RAR strategies to perceptually order objects on length and weight?
5) Is the strategy used affected by the seriation variable?
6) Is the strategy used affected by the number of objects?

The answers to these questions will provide baseline information for future studies of the learning and transfer of strategies for the ordering task. The answers should also have implications for efforts to teach children to order on length and weight.

PROCEDURE

Sample

The sample was drawn from four randomly selected elementary schools of an urban district with 23 elementary schools. Four schools using the SCIS program were excluded from the list because that program provides instruction on the seriation task. None of the schools was in an atypical neighborhood. Each school had small minorities of Black and Latino children. Twenty-four children were randomly selected from the pooled first-grade classes of each school. The mean age of the children was 80.5 months (S.D. = 5.1 months). The mean Metropolitan Reading Readiness score, obtained during the children's kindergarten year, was 65.8 (S.D. = 14.0).

Design

A 4 x 2 x 4 randomized block design (Table 5) was used to investigate the effects of the ordering variable and number of objects on the children's ordering behavior. The school which the children attended was the blocking variable.

Children were randomly selected from the pooled first-grade classes of each of the four selected schools. The names on the class lists were enumerated with the children in a school being selected and tested in the order their numbers were encountered in a random number table. Any child who was unavailable at the time he was selected (and was to be tested) was replaced by the child whose number was encountered next. The eight treatments were randomly assigned to children (without replacement of treatment) until one child had been tested with each treatment. This process was then repeated twice to complete the testing of 24 children. The testing was completed in four consecutive days with each school being completed in one day.

Testing Procedures

The ordering task required the child to place a set of 4, 6, 8, or 10 objects into a row ordered on a named variable (length or weight). The objects for length were 1/4" diameter wooden dowels. Those for weight were covered, 12-ounce styrofoam cups containing lead shot in paraffin. Further specifications for the materials are prseented in Appendix A.

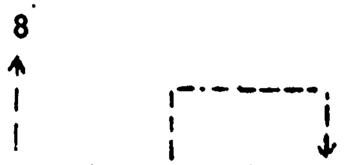
Instructions for the task included the presentation of an ordered row of 5 objects which the child was instructed to examine by looking/hefting. Subsequently the child was asked to put another set of objects into a similar row "according to their length/weight." Alternative instructions were employed if the child failed to form a row or indicated he did not understand. The complete instructions for weight are included in Appendix B. Pilot work revealed that without the sample ordered row, many children indicated they did not understand the instructions. With the sample, most said they understood the first time.

Data Collection

While the child was placing objects into a row, the tester recorded the sequence of object placement on the line along the top of the record sheet. (See Figure 1) The numbers indicate the sequence while the position of the number indicates the relative position of the object in the row. Objects moved from one position to another in the row were recorded as an additional placement (a new number) with an arrow connecting the original and new numbers for that object. Subsequently, the tester determined and recorded the actual rank of the objects (by observing them as they were left by the child) and the correct order. Codes for the rearrangements were also recorded. This record provided the basis for computing the scores used to analyze the performance.

Scoring

Two types of scores were employed. The first type reflects the correctness of the ordering while the second type reflects the strategy used to carry out the task. Both the Spearman rank order correlation coefficient and the Kendall Tau coefficient for the child's final ranking



Sequence	1	2	3	4	5	6	7	9	10	11
Object Number	2	3	(?)	4	(6)	5	6	7	9	8
Correct Order	2	3		4		5	6	7	8	9
Code	0	0	-5	0	-1	0	5	0	0	0

Figure 1

Sample record of an attempt to order 8 objects (object numbers 2-9). A code of -1 means the object was rearranged. A positive integer code indicates the sequence number previously assigned to a rearranged object. A -5 code indicates the object was simply removed from the row (and in this case, placed again later). A zero code indicates the object was not moved following its initial placement.

and the correct ranking were considered as correctness scores. The Kendall Tau was selected primarily because of its tendency to be less negatively skewed. It spreads out the scores near 1.0 thus allowing more discrimination among individuals making a small number of errors.

No single score was identified which reliably indicated the strategy used under all conditions. Therefore, a configuation of scores including the Task Score was used (Table 6). The strategy scores employed in this configuration included:

1) Sequence Score (SS) - This score is the proportion of adjacent pairs of objects which were initially placed sequentially (one after the other) into the row and had none inserted between. A high SS score would be obtained with an EVS strategy and a low SS score with an INS strategy.

2) Tau Sequence Score (TSS) - This score is the Kendall Tau correlation for the objects' actual ranks and the initial sequence in which they were placed into the row. A high TSS score implies accurate use of an EVS strategy while a low TSS score would be obtained with an INS strategy.

3) Number of Rearrangements (NR) - This is simply the number of objects moved directly from one position in the row to another. A relatively large NR would be obtained with an RAR strategy.

Although a high Sequence Score is generally associated with the EVS strategy, it can be spuriously high if the child is simply lining up the objects without ordering. On the other hand, it remains high when the child makes discriminate errors. It also remains relatively high even if the child reverses extremes during the test (e.g. from heaviest to lightest). A high Tau Sequence Score is also associated with the EVS strategy. It, however, depends on correct discriminations and is more drastically affected by a reversal of extremes. Thus, both the Sequence Score and Tau Sequence Score are needed to detect a tendency to use the EVS strategy across differing Task Scores. The absence of rearrangements, accurate ordering with a low Sequence Score and a low Tau Sequence Score indicate the use of an INS strategy.

The most important criteria are those for the ideal EVS and INS strategies. In Table 6 these are labeled "EVS" and "INS" respectively. Patterns that deviate slightly from those for the ideal strategies are labeled "near EVS" and "near INS". Patterns similar to those just mentioned except for less accurate performance are labeled with the additional term "errors." The "errors" patterns are less reliable since the strategy scores do not completely distinguish between discrimination errors and deviations from the ideal strategies. The "error" patterns still represent strong tendencies toward the ideal strategies. The "quasi" designation, however, implies only a very superficial resemblance to the ideal strategies in cases where the resulting ordering is only marginally better than chance.

TABLE 6

CONFIGURATION OF SCORES USED
TO INFER STRATEGY UTILIZATION *
(FOR NUMBER OF REARRANGEMENTS ≤ 1)

Tau Sequence Score	Sequence Score	TASK SCORE Low 0 - .39	Med. Low .40 - .69	Med. High .70 - .89	High .90 - 1.00
Low 0 - 44	Low 0 - 54	Non Performers (No Strategy Inference)	Quasi INS	INS-Errors	INS
	Med. .55 - 69		?	INS-Errors	INS
	High .70 - 1.0		?		
Med. Low .45 - .69	Low		?	Near INS-Errors	Near INS
	Med.		?	?	?
	High		Quasi EVS	?	?
Med. High .70 - .89	Low			?	?
	Med.			?	?
	High		Quasi EVS	Near EVS-Errors	Near EVS
High .90 - 1.00	Low				
	Med.			Near EVS-Errors	Near EVS
	High			EVS-Errors	EVS

*Crossed out areas represent very low probability occurances. Question marks represent cases where no inference about strategy seems warranted.

Analysis of Data

The analysis carried out as the basis for answering each question is described here.

1) How accurate are first grade children in perceptually ordering objects on length and weight?

Task Score frequency distributions, means, and standard deviations were prepared for each testing group and the total group. Consistency across schools was assessed in the multivariate ANOVA for questions 2 and 3.

2) Does the ordering variable (length or weight) affect their accuracy?

3) Does the number of objects (4, 6, 8, or 10) affect their accuracy?

The answers to questions 2 and 3 were based on a multivariate analysis of variance of Task Scores (see Table 5 for the design).

4) To what extent do first grade children employ the EVS, INS, or RAR strategies to order objects perceptually on length and weight?

Children using the EVS and INS strategies were identified using the configuration of scores in Table 6. The proportions of all children who accurately performed the task using EVS, INS, or RAR were prepared as well as the proportions of successful children who used them. The proportions of children in the other categories represented in Table 6 were also prepared.

5) Is the strategy used affected by the seriation variable?

6) Is the strategy used affected by the number of objects?

The answers to questions 5 and 6 were based on frequencies using the chi square statistic where possible.

RESULTS

The accuracy of the children's ordering performance is reported in Table 7 and 8. Forty-four percent (42 children) performed their task with a high level of accuracy ($TS \geq .90$) with all but two of these ordering perfectly ($TS = 1.0$). Sixty three percent of the children who were asked to order on length scored high, while 25 percent of those asked to order on weight performed at that level. The distribution of all Task Scores is distinctly bimodal with this pattern being evident in both the length and weight data. Thus, it appears that while a substantial proportion of the children demonstrated mastery of the ordering task with length and weight, many other children had yet to develop such mastery.

TABLE 8

MEANS AND STANDARD DEVIATIONS
OF TASK SCORES BY SCHOOL,
SERIATION VARIABLE, AND NUMBER OF OBJECTS

Seriation Variable	No. of Objects	School								Total	
		A		B		C		D			
		Mean	SD.	Mean	SD.	Mean	SD	Mean	SD	Mean	SD
Length	4	1.0	0	1.0	0	.89	.19	.89	.19	.95	.13
	6	.69	.54	.73	.46	.53	.50	.73	.46	.67	.43
	8	.93	.12	.79	.30	.72	.37	.52	.44	.74	.32
	10	1.0	0	.61	.02	.86	.23	.90	.18	.84	.19
	Subtotal	.91	.27	.79	.28	.75	.33	.76	.33	.80	.30
Weight	4	.78	.39	.44	.51	.55	.39	.67	.34	.61	.37
	6	.55	.39	.47	.27	.82	.31	.33	.14	.54	.31
	8	.41	.43	.81	.17	.71	.29	.19	.22	.53	.36
	10	.20	.16	.41	.51	.42	.47	.48	.33	.38	.35
	Subtotal	.49	.37	.53	.37	.63	.35	.42	.29	.52	.35
Total		.70	.39	.66	.35	.69	.34	.59	.35	.66	.35

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Seriation Variable	No. of Objects	School								Total	
		A		B		C		D			
		Mean	SD.	Mean	SD.	Mean	SD	Mean	SD	Mean	SD
Length	4	1.0	0	1.0	0	.89	.19	.89	.19	.95	.13
	6	.69	.54	.73	.46	.53	.50	.73	.46	.67	.43
	8	.93	.12	.79	.30	.72	.37	.52	.44	.74	.32
	10	1.0	0	.61	.02	.86	.23	.90	.18	.84	.19
	Subtotal	.91	.27	.79	.28	.75	.33	.76	.33	.80	.30
Weight	4	.78	.39	.44	.51	.55	.39	.67	.34	.61	.37
	6	.55	.39	.47	.27	.82	.31	.33	.14	.54	.31
	8	.41	.43	.81	.17	.71	.29	.19	.22	.53	.36
	10	.20	.16	.41	.51	.42	.47	.48	.33	.38	.35
	Subtotal	.49	.37	.53	.37	.63	.35	.42	.29	.52	.35
Total		.70	.39	.66	.35	.69	.34	.59	.35	.66	.35

TABLE 9

ANALYSIS OF VARIANCE OF
TASK SCORES

Source	df	MS	F
School	3	.0570	.5180
Seriation Variable	1	1.9494	17.7015*
No. of Objects	3	.1554	1.4109
School x Variable	3	.1296	1.1772
School x No. Objects	9	.0867	.7874
Variable x No. Objects	3	.0975	.8857
Sch. x Var x No. Objects	9	.0890	.8086
Error (within cell)	64	.1101	—

*Significant (p < .0001)

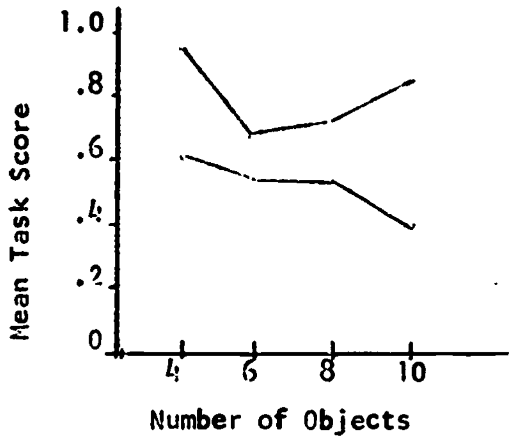

Figure 2 - Mean Task Scores By Seriation Variable and Number of Objects

The mean Task Scores and standard deviations are presented in Table 8. The bimodal nature of the distribution is reflected in relatively high standard deviations and means which are not very representative.

A multivariate ANOVA was performed on the Task Scores using the school the child attended as a blocking variable (see Table 5). No significant school effect was obtained (Table 9). This, together with the rather unifrom variability indicates that the level of accuracy of the children's ordering was stable across schools.

The ANOVA was also used to assess the effects of seriation variable (length or weight) and number of objects (4, 6, 8 or 10) on the accuracy of seriation (Table 9 and Figure 2). As would be expected from the large difference between mean Task Scores for length (.80) and weight (.51), the seriation variable main effect was highly significant ($P < .0001$). However, neither the number of objects main effect nor any interaction effects were significant.

The primary purpose of the study was to examine the strategies by which the children ordered the objects. Table 10 indicates the extent of use of the EVS, INS and RAR strategies (as defined in Table 6) by the 42 children performing the task with a high degree of accuracy ($TS \geq .90$). Over one third (36%) used an ideal EVS strategy, one fourth (26%) used an ideal INS strategy, and 7% used an RAR strategy. Thus, over two thirds (69%) used a highly systematic approach to the task. Another 9% were identified as using near EVS or near INS strategies leaving only 21% who deviated substantially from the ideal strategies. A similar pattern was obtained for the eight children with medium high Task Scores ($.70 \leq TS < .90$). Apart from their errors, only two children deviated substantially from the ideal strategies. Of the 11 children with medium low Task Scores ($.40 \leq TS < .70$), six were designated as quasi-EVS or quasi-INS.

TABLE 10

USE OF STRATEGIES BY CHILDREN
WITH HIGH TASK SCORES ($TS \geq .90$)

Seriation Variable	N with TS ≥ .90	Strategy: EVS Ideal f	EVS Ideal %	EVS Near f	EVS Near %	INS Ideal f	INS Ideal %	INS Near f	INS Near %	RAR f	RAR %	Unknown or Mixed f	Unknown or Mixed %
Length	30	7	23%	2	6%	10	33%	1	3%	2	6%	8	27%
Weight	12	8	67%	1	8%	1	8%	0	0%	1	8%	1	8%
Total	42	15	36%	3	7%	11	26%	1	2%	3	7%	9	21%

Only 13 children rearranged any objects at all. Of these only 5 rearranged more than one. Three of these made two rearrangements to produce a corrected row of 4 objects and were judged to be using an RAR strategy. One child used six rearrangements while ordering 8 objects with an otherwise EVS strategy. No pattern was detected in the rearrangements so the person was judged to be using an unknown strategy. This was the only case who might be viewed as trial-and-error. The remaining child with more than 1 rearrangement obtained a low Task Scoré despite rearranging 3 objects in the row.

The effects of the seriation variable and number of objects on the strategy used were assessed by employing the chi square statistic with the frequencies presented in Table 11. Because of the small frequencies involved, only the total EVS and INS data were used. Also, the data for 4 and 6 objects were combined as were those for 8 and 10 objects. The Yates correction for small frequencies was employed in computing chi square. Although there was a tendency for the INS strategy to be used less frequently with weight than with length, the effect was not significant (Table 12). Neither did the number of objects significantly effect the relative use of INS and EVS strategies (Table 13).

Also examined were the effects of seriation variable and number of objects on the extent to which any of the three recognized strategies were used (Tables 14 and 15). Although there were more cases of no or unknown strategies with length than with weight and with 8 and 10 objects than with 4 and 6, neither effect was significant.

DISCUSSION

The bimodal distribution of Task Scores together with the relatively high proportion of successful children who used the recognized seriation strategies reveal a surprising degree of systematic behavior by many of the first grade children. Trial and error attempts were almost non existent. These results indicate that our strategy models are quite useful in characterizing the successful approaches first grade children use in perceptually ordering objects on length and weight. Thus, our results both confirm and extend the findings obtained by Baylor and Gascon (1974) with weight seriation using a balance. Within the ranges examined the basic strategies appear relatively stable across both the seriation variable and the number of objects.

The results of the present study are also generally compatible with the Piagetian research. The time line for acquisition of the abilities to order on length and weight is supported. Also, the tendency for children to either perform the task quite systematically or very poorly is consistent with the Piagetian view that ability to perform the tasks depends on the child's having acquired an underlying cognitive structure without which the child cannot even comprehend the task. However, as stated above, the orientation of the present research with respect to the Piagetian research is not toward the acceleration of development,

TABLE 11
FREQUENCIES FOR ALL STRATEGY CATEGORIES
BY SERIATION VARIABLE AND NUMBER OF OBJECTS

Seriation Variable	No. of Objects	Strategy: EVS: Ideal EVS	Near EVS	EVS-Errors	Near EVS-Errors	Total EVS	INS: Ideal INS	Near INS	INS-Errors	Near INS-Errors	Total INS	RAR	Total Strategy	Unknown Strategy: High TS	Med. High TS	Quasi Strategy: Quasi EVS	Quasi INS	Med. Low TS	Non-Performer (low TS)
Length	4	4	0	0	0	4	4	0	0	0	4	2	10	0	0	0	0	2	0
	6	1	1	0	0	2	3	0	0	0	3	0	5	2	0	0	0	1	4
	8	0	1	0	1	2	1	0	0	1	2	0	4	4	0	1	0	0	3
	10	2	0	0	0	2	2	1	0	0	3	0	5	2	0	1	1	3	0
	Subtotal	7	2	0	1	10	10	1	0	1	12	2	24	8	0	2	1	6	7
Weight	4	4	0	0	0	4	0	0	0	0	0	1	5	0	0	1	0	0	6
	6	2	0	0	1	3	0	0	0	0	0	0	3	1	0	3	0	0	5
	8	2	0	1	0	3	0	0	1	0	1	0	4	0	2	0	0	2	4
	10	0	1	0	0	1	1	0	1	0	2	0	3	0	0	0	1	0	8
	Subtotal	8	1	1	1	11	1	0	2	0	3	1	15	1	2	4	1	2	23
Total		15	3	1	2	21	11	1	2	1	15	3	39	9	2	6	2	8	30

TABLE 12

FREQUENCY OF EVS AND INS BY SERIATION VARIABLE

	EVS	INS	
Weight	11	3	14
Length	10	12	22
	21	15	36

Chi Square[1] = 2.62

df = 1

not significant

TABLE 14

FREQUENCY OF EVS AND INS BY NUMBER OF OBJECTS

	EVS	INS	
8 + 10	8	8	16
4 + 6	13	7	20
	21	15	36

Chi Square[1] - .32

df = 1

not significant

TABLE 13

FREQUENCY OF ANY STRATEGY BY SERIATION VARIABLE

($TS \geq .70$)

	Strategy	No or Unknown strategy	
Weight	15	3	18
Length	24	8	32
	39	11	50

Chi Square[1] = .56

df = 1

not significant

TABLE 15

FREQUENCY OF ANY STRATEGY BY NUMBER OF OBJECTS

($TS \geq .70$)

	Strategy	No or Unknown strategy	
8 + 10	16	8	24
4 + 6	23	3	26
	39	11	50

Chi Square[1] = 2.30

df = 1

not significant

1 Chi Square was calculated with the Yates correction for low cell frequencies.

but toward the use of the developmental level as an individual difference variable which may influence what science concepts, tasks and strategies can be learned. Along with Voelker (1972), we urge other science educators to adopt such an orientation.

The most important implication of the results of this study is the viability of the strategy for task performance as a construct in educational theory. The degree to which such strategies may be amenable to instruction, and the extent to which they may mediate transfer of learning remain to be determined. However, the fact that even young children approach quite systematically at least some tasks which they understand suggests that strategy instruction may be practical. This fact certainly indicates that attempts to teach tasks should take into account the learner's capacity and tendency to use systematic approaches.

Research should be planned to assess the learnability of strategies for performing tasks, the role of strategies in transfer, and the effects individual differences may have on strategy use. The strategies typically used by learners or experts may turn out to be useful devices for teaching less successful learners. The Concept-Task-Strategy model described above should provide a useful framework within which to conduct such research. The strategy modeling techniques of Newell and Simon (1972) may also be an important tool in these efforts.

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APPENDIX A

SPECIFICATIONS FOR OBJECTS USED IN THE SERIATION TASK

Object No.	Weight[1] of Cups[3] (grams)	Length of Dowels[4] (centimeters)
1	10	5.5
2	64	6.0
3	169	6.5
4	324	7.0
5	529	7.5
6	784	8.0
7	1089	8.5
8	1444	9.0
9	1849 (1800)[2]	9.5
10	2310 (2100)	10.0

Set of 4: objects 4–7. Set of 6: objects 3–8. Set of 8: objects 2–9. Set of 10: objects 1–10.

[1]The square roots of adjacent weights differ by a constant amount (0.5). This approximates a psychologically equal interval for weight (Bessemer, 1973). A difference of 0.5 seems sufficient for discrimination by first graders if they are careful. A larger interval is impractical for 10 objects due to the large weight required for the heaviest object.

[2]The actual weights used are indicated in parentheses.

[3]These were identical 12 ounce styrofoam cups filled with lead shot in paraffin to achieve the indicated weight. Plastic covers were glued on.

[4]These were cut from wooden dowelling of 3/8" diameter.

APPENDIX B

INSTRUCTIONS FOR THE SERIATION TASK (WEIGHT)

Introduction: Weight

1. Place the ordered row of (5) cups before the subject.

2. "Mr. _______ lined these up according to their weight. Pick up each one and find out how heavy it is. See how each one is heavier than the next one? In a moment I would like you to make a row like this with some other cups. Do you understand what to do?"

Instructions for Seriation Task: Weight

1. Place objects before subject.

2. "Please put these cups in a row according to their weight. You may pick them up to find out how heavy they are if you want to."

   "Do you understand what to do?"

   Did subject form a row?

3. (If no) "Put these cups side by side from heaviest to lightest or else from lightest to heaviest."

   "Do you understand what to do?"

   Did subject form row?

4. (If still no) "Some of these cups are lighter and some are heavier. Put them in a row with the heaviest on one end the lightest on the other end. Put the others in between where they belong.

   "Do you understand what to do?"

   Did subject form a row?

5. (If yes) "Good. You may begin."