DOCUMENT RESUME

ED 049 036 SE 010 936

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TITLE The Level of Mastery of Selected Classificatory Science Concepts.

INSTITUTION Wisconsin Univ., Madison. Research and Development Center for Cognitive Learning.

SPONS AGENCY Office of Education (DHEW), Washington, D.C.
BUREAU NO BR-5-0216
PUB DATE Feb 71
CONTRACT OEC-5-10-154
NOTE 16p.; Paper presented at the Annual Meeting of the American Educational Research Association (Feb. 4-7, 1971, New York, N.Y.)

EDRS PRICE EDRS Price MF-$0.65 HC Not Available from EDRS.
DESCRIPTORS Achievement, Biology, Classification, Earth Science, *Elementary School Science, *Evaluation, *Physical Sciences, Science Tests, *Scientific Concepts, *Tests

ABSTRACT

The purpose of this study was to assess the potential use of A Schema for Testing the Level of Concept Mastery in measuring attainment of classificatory concepts in science. Classificatory concepts from the biological, earth, and physical sciences were included. For each of the 30 concepts included in the study a 12-item test was constructed to measure children's attainment of each of twelve schema tasks. The schema is useful in identifying and analyzing classificatory concepts and preparing related concept attainment tests. The tests have been administered to sixth-grade children to determine the level of concept attainment by concept and among science areas. [Not available in hardcopy due to marginal legibility of original document.] (Author/AL)

THE LEVEL OF MASTERY OF SELECTED CLASSIFICATORY SCIENCE CONCEPTS

by

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A paper presented at the
1971 AERA Convention
New York, New York
February 4-7, 1971

The research reported herein was performed pursuant to a contract with the United States Office of Education, Department of Health, Education, and Welfare, under the provisions of the Cooperative Research Program. The opinions expressed in this publication do not necessarily reflect the position or policy of the Office of Education and no official endorsement by the Office of Education should be inferred.

Center No. C-03/Contract OE 5-10-154

Problem

The purpose of this study was to determine the level of mastery of selected classificatory science concepts.* Related problems were

1. to determine whether relationships exist among attainment of classificatory concepts in the biological, earth, and physical science areas and
2. to determine whether there is a hierarchy of levels of attainment of classificatory concepts according to the nature of a concept and the respective science area.

Procedure

The fourth-grade texts from the six elementary science series available to the teachers in the school system where the concept attainment tests were to be administered were analyzed. The concepts identified in these analyses were used to prepare master lists of classificatory concepts from three science areas (biological, earth, and physical). Initially, ten concepts were randomly selected from each of the three lists and analyzed as follows:

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*A classificatory concept possesses three characteristics.

1. There is more than one example of the concept.
2. The properties of the concept can be described.
3. The concept can be labelled (named) by a word or a compound word.

1. Supraordinate, coordinate, and subordinate concepts were identified.
2. Criterial, other relevant, and irrelevant attributes were identified.
3. A definition was constructed.
4. Examples and non-examples were identified (Voelker & Sorenson, 1971)

Concepts that could not be analyzed using this system were randomly replaced from the master lists until 30 concepts, 10 per area, had been analyzed.

A 12-item test was constructed for each of these 30 concepts. Each test included one item designed to measure whether a child could perform these tasks (Voelker & Sorenson, 1971).

1. Given name of attribute, select example of attribute.
2. Given example of attribute, select name of attribute.
3. Given name of concept, select example of concept.
4. Given name of concept, select non-example of concept.
5. Given example of concept, select name of concept.
6. Given name of concept, select relevant attribute.
7. Given name of concept, select irrelevant attribute.
8. Given meaning of concept, select name of concept.
9. Given name of concept, select meaning of concept.
10. Given name of concept, select supraordinate concept.
11. Given name of concept, select subordinate concept.
12. Given two concepts, select principle relating them.

These tasks were part of a schema for testing the level of concept mastery (Frayer, Fredrick, & Klausmeier; 1969).

Data Collection

The 360 items were administered to beginning sixth-grade children in five sets, each set consisting of the 72 items for six of the 30 concepts placed in random order. Data from this testing were utilized to revise the tests in preparation for the main study.

The revised tests were administered to beginning sixth-grade children--186 boys and 259 girls. Analyses of the results from this testing provide the basis for the following discussion.

Tests of Concept Attainment

The mean scores attained by the boys on the 30 tests of concept attainment ranged from 6.62 to 9.61 out of a possible attainable score of 12.00 (Table 1). For the tests in both the biological and the physical science areas, the difference between lowest and highest mean scores was approximately two points, whereas in the earth science area, there was less than a one point difference between the lowest and the highest mean score. Overall the highest mean scores were obtained in the biological science area and the lowest mean scores in the physical science area.

The range of mean scores for the girls on the 30 concept attainment tests was in excess of four points, from 6.04 to 10.44. The pattern of mean scores for the concept tests within the specific science areas

Table 1

Means and Reliabilities for Tests of Science Concept Attainment

Concept	Boys#		Girls*	
	$\bar{X}$	R	$\bar{X}$	R
Birds	7.88	.6249	9.43	.5510
Cell	7.33	.6124	7.29	.5404
Fish	9.42	.7077	10.08	.6491
Heart	8.79	.7384	9.36	.7212
Invertebrate	7.40	.7297	7.42	.6901
Lens	7.87	.6766	8.08	.6021
Lungs	8.95	.7874	9.45	.7799
Mammal	9 61	.7592	10.44	.7626
Muscle	8.07	.6662	7.99	.7005
Pore	8.26	.7203	8.85	.7652
Cloud	8.22	.7169	8.67	.5849
Core	8.68	.7508	8.99	.6610
Fossil	8.81	.7003	9.36	.6224
Glacier	8.32	.6635	8.69	.6707
Meteor	7.65	.7231	7.67	.6386
Moon	8.57	.7636	8.34	.7801
Planet	8.32	.6839	8.67	.6774
Sedimentary Rock	7.91	.7137	8.75	.7186
Volcano	8.78	.6525	9.27	.6022
Wind	8.76	.7122	9.56	.6698
Conductor	6.62	.6781	6.04	.6590
Evaporation	7.99	.7081	8.29	.6711
Expansion	7.51	.7053	7.80	.7285
Friction	7.69	.6173	7.49	.5174
Liquid	8.89	.6737	9.22	.6792
Melting	7.75	.6538	8.37	.6180
Molecule	6.62	.5994	6.99	.5649
Solid	8.58	.7658	9.56	.6883
Sound	8.16	6913	8.54	.6621
Thermometer	8.34	.7097	8.68	.5707

#N = 186

*N = 259

was similar to that observed for the boys. The greatest differences between the lowest and highest mean scores occurred in the biological and physical science areas. Also, the highest means were obtained for concept tests in the biological science area and the lowest means were obtained for the concept tests in the physical science area.

The girls attained a higher mean score than the boys on 25 of the 30 concept tests. This overall pattern of mean scores for girls being greater than that for boys was also noted in each of the three specific science areas; girls scored higher means on eight or more of the concept tests in each of the areas. (Note at this point that no consideration has been given to differences in test reliabilities for the boys and the girls. Note also that the tests have only 12 items.)

An examination of Table 2 reveals the following:

1. For both the boys and the girls the concepts for which the highest mean scores were attained were MAMMAL and FISH; both from the biological science area. The four concept tests on which the children earned the lowest scores were also identical for both the girls and the boys--INVERTEBRATE, CELL, MOLECULE, CONDUCTOR.
2. The ten concept tests with highest ranked mean scores included nine of the same concepts for the girls and the boys. Five of these concepts were from the biological science area and three from the earth science area. Eight of the ten concept tests with the lowest ranked mean scores were the same for

Table 2

Rand Orders of Mean Scores on Tests
of Science Concept Attainment

Concept	Boys#		Girls*	
	$\bar{X}$	Rank	$\bar{X}$	Rank
Mammal	9.61	1	10.44	1
Fish	9.42	2	10.08	2
Lung	8.95	3	9.45	5
Liquid	8.89	4	9.22	10
Bird	8.88	5	9.43	6
Fossil	8.81	6	9.36	7.5
Heart	8.79	7	9.36	7.5
Volcano	8.78	8	9.27	9
Wind	8.76	9	9.56	3.5
Core	8.68	10	8.99	11
Solid	8.58	11	9.56	3.5
Moon	8.57	12	8.34	20
Thermometer	8.34	13	8.68	15
Plant	8.32	14.5	8.67	16.5
Glacier	8.32	14.5	8.69	14
Pore	8.26	16	8.85	12
Cloud	8.22	17	8.67	16.5
Sound	8.16	18	8.54	18
Muscle	8.07	19	7.99	23
Evaporation	7.99	20	8.29	21
Sedimentary Rock	7.91	21	8.75	13
Lens	7.87	22	8.08	22
Melting	7.75	23	8.37	19
Friction	7.69	24	7.49	26
Meteor	7.65	25	7.67	25
Expansion	7.51	26	7.80	24
Invertebrate	7.40	27	7.42	27
Cell	7.33	28	7.29	28
Molecule	6.62	29.5	6.99	29
Conductor	6.62	29.5	6.04	30

#N = 186

*N = 259

the girls and the boys; four from the physical science area and three from the biological science area.

There was a difference of four to eight positions in the rank order of the mean scores on seven of the 30 concept attainment tests. The mean test scores for boys were at a higher rank order for five of these seven. There was one biological science concept in this group of ranked differences, the mean score for girls receiving the higher rank. In both the physical science and the earth science areas, there were three concepts with wide differences in the rank orders of the mean scores. Mean test scores for the boys received the higher rank order for all three physical science concepts and two of the three earth science concepts.

Tests of Task Attainment.

Data were also analyzed in terms of the mean scores earned for each of the 12 tasks across the 30 concepts (Table 3). Each of the 30 concept tests consisted of 12 items. The girls attained higher mean scores than the boys on each of the 12 task attainment tests. For both the boys and the girls the first five tasks from the schema referred to previously (page 2) received the highest five ranks (Table 4). They did not progress from one to five but the mean scores varied only slightly. For the boys it is of note that the rank orders of the mean scores for Tasks 6 and 7, selection of relevant and irrelevant attributes, were 10 and 12, respectively. Ranks of the other means appear to follow the general progression of the schema. For the girls it is of note that the rank order of of the mean score on Task 7 was 11. All else seems to follow the general order of the schema.

Table 3

Mean Scores and Reliabilities for Tests of Task Attainment

Task	Boys#		Girls*	
	$\bar{X}$	R	$\bar{X}$	R
1	23.17	.8447	24.54	.8264
2	22.22	.8676	23.44	.8355
3	23.50	.8002	24.11	.7202
4	23.34	.7646	23.65	.6638
5	22.95	.8522	23.57	.7815
6	18.76	.8508	20.18	.8322
7	16.76	.8499	18.05	.8261
8	20.17	.8917	21.37	.8537
9	19.06	.8717	20.26	.8600
10	20.67	.8847	21.04	.8659
11	18.82	.8312	19.49	.7733
12	17.32	.8305	17.63	.8125

#N = 186

*N = 259

Table 4

Rank Orders of Mean Scores on Tests of Task Attainment

Task	Boys#		Girls*	
	$\bar{X}$	Rank	$\bar{X}$	Rank
1	23.17	3	24.54	1
2	22.22	5	23.44	5
3	23.50	1	24.11	2
4	23.34	2	23.65	3
5	22.95	4	23.57	4
6	18.76	10	20.18	9
7	16.76	12	18.05	11
8	20.17	7	21.37	6
9	19.06	8	20.26	8
10	20.67	6	21.04	7
11	18.82	9	19.49	10
12	17.32	11	17.63	12

#N = 186

*N = 259

While no attempt has been made to determine whether a hierarchy of concept attainment tasks can be inferred from these data a Simplex Analysis was run on pilot study data for 12 of the concepts (Guttman, L., 1954). See Table 5.

Table 5

Simplex Analyses for Selected Arrangements of Task Attainment Scores*

	q^2
1. 5 4 3 2 1 7 8 9 10 11 6 12	.8239
2. 3 4 5, 1 2, 6 7, 8 9, 10 11, 12	.8133
3. 3 4 5, 1 2, 6 7 8 9, 10 11, 12	.7176

Criterion Levels

Arbitrary levels of concept attainment were established and the data analyzed accordingly (Tables 6, 7, and 8). It was noted when less than 60, 70, or 80% of the students achieved the respective level of attainment on the 12 tasks of the schema.

Overall the boys had difficulty with Tasks 7 and 12 at the 60% level. No difficulty was noted in the biological science area, some in the earth science area (7, 11) and a measurable amount of difficulty in the physical science area (6, 7, 9, 11, 12). For the girls, no

Table 6
Test Items Correctly Answered by Less Than 60% of the Respondents

Concept	Task											
	1	2	3	4	5	6	7	8	9	10	11	12
Bird									#*	*		#
Cell	#*			*				#*	#*	#*	#*	
Fish										#*		
Heart		#										#*
Invertebrate			#*	#*					#*		*	#*
Lens							#*	#*	#*			#*
Lungs						#						
Mammal												
Muscle						#*	#*				#*	
Pore						#	#*				#	
Cloud		#*				#	#*			*		#*
Core						#*	#*			#*		
Fossil			#*				#*					
Glacier	#									#		#*
Meteor			*			#*				#*	#*	
Moon							#*				#*	
Planet											#*	
Sedimentary Rock					#		#		#		#*	#
Volcano											#	#*
Wind							#	#				
Conductor			#*	#*	#*	*	#*	*	#*	#*	#*	#*
Evaporation					*	#*	#*				#	*
Expansion	#					#*	#*	#			#*	#*
Friction				#*		#*	#*		#*			#
Liquid							#		#*			
Melting		#*			*	#	#				#	#*
Molecule			#*	#*	#*		#*		#*	#*	#*	#*
Solid									#*			
Sound							#*		#			#*
Thermometer						#	#*				#*	#*

#Boys

*Girls

Table 7

Test Items Correctly Answered by Less Than 70% of the Respondents

Concept	Task											
	1	2	3	4	5	6	7	8	9	10	11	12
Bird							#*		#*	#*		#*
Cell	#*	#*		#*	#		#	#*	#*	#*	#*	#*
Fish						#				#*		
Heart		#*										#*
Invertebrate			#*	#*		#	#	#*	#*	#	*	#*
Lens				#*	#*	#*	#*	#*	#*		#	#*
Lungs						#*	#*	#	#			#
Mammal						#	#				#	
Muscle	#*	#		*		#*	#*		#*		#*	#*
Pore			#		#*	#*	#*			#	#*	#*
Cloud		#*				#*	#*	#		#*		#
Core						#*	#*		#	#*	#	
Fossil			#*				#*					#
Glacier	#	#*			*	#*	#*			#*	#*	#*
Meteor	#		#*			#*	#*	#	#	#*	#*	#*
Moon					*		#*	#*	#*	#*	#*	#*
Planet		#					#*	#*	*	#	#*	#*
Sedimentary Rock			#		#*	#	#*	#*	#		#*	#*
Volcano					#*	#	#		#*		#*	#*
Wind							#*	#*				#
Conductor			#*	#*	#*	#*	#*	#*	#*	#*	#*	#*
Evaporation			#*		#*	#*	#*	#*	#*		#*	#*
Expansion	#*	#*		#		#*	#*	#*	#*	#	#*	#*
Friction				#*		#*	#*	*	#*	#*		#*
Liquid						#	#*	#*	#*			
Melting	#	#*				#*	#*	#*	#		#*	#*
Molecule	#		#*	#*	#*	#	#*	#*	#*	#*	#*	#*
Solid	#*	#					#	#	#*	#*		
Sound						#	#*	#*	#	#*	*	#*
Thermometer						#*	#*	#*			#*	#*

#Boys

*Girls

Table 8

Test Items Correctly Answered by Less Than 80% of the Respondents

Concept	Task											
	1	2	3	4	5	6	7	8	9	10	11	12
Bird						#*	#*	#*	#*	#*		#*
Cell	#*	#*	#*	#*	#*	#*	#*	#*	#*	#*	#*	#*
Fish						#	#	#*	#*	#*	#	#*
Heart	#*	#*			#	#*	#*		#	#	#*	#*
Invertebrate	*		#*	#*	#*	#*	#*	#*	#*	#*	#*	#*
Lens				#*	#*	#*	#*	#*	#*		#*	#*
Lungs						#*	#*	#*	#*	#	#*	#*
Mammal			#			#	#*				#	
Muscle	#*	#*	*	#*	*	#*	#*	#*	#*	*	#*	#*
Pore			#*	#	#*	#*	#*	#		#*	#*	#*
Cloud	#	#*				#*	#*	#*	#*	#*		#*
Core		#				#*	#*		#*	#*	#*	#*
Fossil			#*			#*	#*	#	#	#	#	#*
Glacier	#*	#*			#*	#*	#*		#	#*	#*	#*
Meteor	#*	#	#*		#*	#*	#*	#*	#*	#*	#*	#*
Moon	#	#			#*	*	#*	#*	#*	#*	#*	#*
Planet		#*				#*	#*	#*	#*	#*	#*	#*
Sedimentary Rock			#*	#*	#*	#*	#*	#*	#*	#	#*	#*
Volcano	#	*		#	*	*	#*	#	#*	#	#*	#*
Wind	#		#	*			#*	#*	#*	#*	#	#*
Conductor		#	#	#*	#*	#*	#*	#*	#*	#*	#*	#*
Evaporation	*	#	#*		#*	#*	#*	#*	#*	#*	#*	#*
Expansion	#*	#*	*	#	#	#*	#*	#*	#*	#*	#*	#*
Friction			*	#*	#*	#*	#*	#*	#*	#*	#*	#*
Liquid		#*			*	#*	#*	#*	#*	#*		#*
Melting	#*	#*				#*	#*	#*	#	#*	#*	#*
Molecule	#*	#	#*	#*	#*	#	#*	#*	#*	#*	#*	#*
Solid	#*	#*				#*	#*	#*	#*	#*		#
Sound	#					#*	#*	#*	#*	#*	#*	#*
Thermometer	#	#		#*		#*	#*	#*	#		#*	#*

#Boys

*Girls

particular difficulty was noted except in the physical science area (6, 7, 9, 12).

In moving from the 60% level to the 70% level a notable increase in difficulty was evident. For both the boys and the girls, there was difficulty with Tasks 6 through 12 for the physical science concepts. The girls had less difficulty in the biological and earth science areas, particularly in the biological science area. Overall the girls had less difficulty with Tasks 6 and 10 than did the boys.

In moving to the 80% level it is noticed that the children begin to experience difficulty with some of the first five tasks of the schema. The major difference between the boys and the girls is that except in the biological science area, the boys are having difficulty with Tasks 1 and 2; whereas for the girls, difficulty appears only in the physical science area. Also, of note, is that Task 5 produces difficulty for the girls overall and in each of the subject-matter areas; whereas, the boys experienced difficulty with this task only in the physical science area.

Discussion

Several comments related to the use of the schema in analyzing concepts and construction test items are in order.

1. It is possible to identify classificatory concepts in science using the aforementioned concept analysis system.
2. The proportion of science concepts fitting the definition of classificatory concept is relatively small.

3. Not all science concepts which fit the definition of classificatory concept are necessarily formulated by using classification rules specific to the science area.
4. The random concept-selection procedure permits the inclusion of concepts of low priority from the science disciplines.
5. The mutually exclusive nature of the schema tasks makes it difficult to construct test items which measure discrete concept attainment tasks.

Tentative conclusions based on this preliminary data analysis are:

1. It appears from the item statistics that the girls are doing more guessing than the boys.
2. The fact that the boys had more difficulty with Tasks 7 and 12 than the girls may be attributed to carelessness in reading the items.
3. It appears at first glance that there is a hierarchy of levels of concept attainment implied in the schema.
4. As anticipated, the children had most difficulty with the physical science concepts. As a group the physical science concepts are more theoretical in nature than the concepts in the biological and earth science areas.

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