DOCUMENT RESUME

ED 065 348 | 24 | SE 014 429

AUTHOR	Harris, Margaret L.; Voelker, Alan M.
TITLE	An Analysis of Content and Task Dimensions of Science Items Designed to Measure Level of Concept Attainment.
INSTITUTION	Wisconsin Univ., Madison. Research and Development Center for Cognitive Learning.
SPONS AGENCY	Office of Education (DHEW), Washington, D.C.
REPORT NO	TR-198
BUREAU NO	BR-5-0216
PUB DATE	Nov 71
CONTRACT	OEC-5-10-154
NOTE	39p.
EDRS PRICE	MF-$0.65 HC-$3.29
DESCRIPTORS	Cognitive Processes; *Concept Formation; Content Analysis; *Evaluation; Intellectual Development; *Scientific Concepts; Test Construction; Thought Processes

ABSTRACT

Content and task dimensions of science items were studied using factor analytic techniques. These items were developed to measure concept attainment using a completely crossed design with 30 concepts and 12 tasks. Conventional factor analyses were performed, separately for boys and girls, for concept scores and for task scores. Three-mode factor analyses were performed. The main conclusions drawn from the results of the conventional factor analyses are that all 30 of the concepts are measures of a single functional relationship existing among the concepts, and that all 12 tasks are measures of a single underlying ability or latent trait. The three-mode results indicate that there are no important concept-task interactions for the idealized persons, thus it is reasonable to regard the concepts and the tasks as being two independent modes. (Author/CP)

AN ANALYSIS OF CONTENT AND TASK DIMENSIONS OF SCIENCE ITEMS DESIGNED TO MEASURE LEVEL OF CONCEPT ATTAINMENT

WISCONSIN RESEARCH AND DEVELOPMENT
CENTER FOR COGNITIVE LEARNING

1

Technical Report No. 198

AN ANALYSIS OF CONTENT AND TASK DIMENSIONS OF SCIENCE ITEMS DESIGNED TO MEASURE LEVEL OF CONCEPT ATTAINMENT

by
Margaret L. Harris and Alan M. Voelker

Report from the Project on
A Structure of Concept Attainment Abilities

Robert E. Davidson, Lester S. Golub, Herbert J. Klausmeier,
Thomas A. Romberg, B. Robert Tabachnick, Alan M. Voelker
Principal Investigators

and
The Quality Verification Program
Mary R. Quilling, Director

Wisconsin Research and Development
Center for Cognitive Learning
The University of Wisconsin
Madison, Wisconsin

November 1971

Published by the Wisconsin Research and Development Center for Cognitive Learning, supported in part as a research and development center by funds from the United States Office of Education, Department of Health, Education, and Welfare. The opinions expressed herein 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

Statement of Focus

The Wisconsin Research and Development Center for Cognitive Learning focuses on contributing to a better understanding of cognitive learning by children and youth and to the improvement of related educational practices. The strategy for research and development is comprehensive. It includes basic research to generate new knowledge about the conditions and processes of learning and about the processes of instruction, and the subsequent development of research-based instructional materials, many of which are designed for use by teachers and others for use by students. These materials are tested and refined in school settings. Throughout these operations behavioral scientists, curriculum experts, academic scholars, and school people interact, insuring that the results of Center activities are based soundly on knowledge of subject matter and cognitive learning and that they are applied to the improvement of educational practice.

This Technical Report is from the Project on the Structure of Concept Attainment Abilities in Program 1. The general objectives of this project are to identify basic concepts in language arts, mathematics, science, and social studies appropriate at a given grade level; to develop tests to measure achievement of these concepts; and to develop and identify reference tests for cognitive abilities. These will be used to study the relationships among learned concepts in various subject matter areas, cognitive abilities, and possibly, certain cognitive styles. The result of these will be a formulation of a model of structure of abilities in concept attainment.

Contents

List of Tables

List of Figures

Abstract

Content and task dimensions of science items were studied using factor analytic techniques. These items were developed to measure concept attainment using a completely crossed design with 30 concepts and 12 tasks. Conventional factor analyses were performed, separately for boys and girls, for concept scores and for task scores. Three-mode factor analyses were performed.

The main conclusions drawn from the results of the conventional factor analyses are that all 30 of the concepts are measures of a single functional relationship existing among the concepts, and that all 12 tasks are measures of a single underlying ability or latent trait. The three-mode results indicate that there are no important concept-task interactions for the idealized persons, thus it is reasonable to regard the concepts and the tasks as being two independent modes.

I
Introduction

The primary objective of the project entitled "A Structure of Concept Attainment Abilities" (hereafter referred to as the CAA Project) is to formulate one or more models or structures of concept attainment abilities, and to assess their consistency with actual data. The major steps for attaining this primary objective were:

1. To identify basic concepts in language arts, mathematics, science, and social studies appropriate at the fourth grade level,

2. To develop tests to measure achievement of these concepts,

3. To identify reference tests for cognitive abilities, and

4. To study the relationships among learned concepts in these four subject matter fields and the identified cognitive abilities.

This paper contains a report of the factor analytic study of the content and task dimensions of the science items that were developed as one aspect of Step 2. The study is a necessary intermediate step between Step 2 and Step 4; some reduction in the number of concepts for each subject matter field from the 30 selected ones for which tests were developed is mandatory in order to facilitate Step 4.

Nature of Science Items

Concepts may be defined in one or more of four ways: (a) structurally, in terms of perceptible or readily specifiable properties or attributes; (b) semantically, in terms of synonyms or antonyms; (c) operationally, in terms of the procedures employed to distinguish the concept from other concepts; or (d) axiomatically, in terms of logical or numerical relationships (Klausmeier, Harris, Davis, Schwenn, & Frayer, 1968). "A concept exists whenever two or more distinguishable objects or events have been grouped or classified together and set apart from objects on the basis of some common feature or property of each" (Bourne, 1966, p. 1). A concept adhering to Bourne's definition might be called a classificatory one and seemingly is the same as the structural type described by Klausmeier, et al. (1968). Such a concept definition served as the basis for selection and analysis of subject matter concepts with which this project is concerned.

Many different types of performance might be taken as the critical evidence that a student does or does not understand a given concept. Thus, as a part of this project it is necessary to have a schema for measuring understanding of concepts. Such a schema was developed by Frayer, Fredrick, and Klausmeier (1969) and was used by the CAA Project to assess concept attainment. The "Schema for Testing the Level of Concept Mastery" consists of 13 types of questions, each requiring the examinee to perform a different task. The schema also allows for selection of an answer (multiple-choice type questions) or for production of an answer (completion type questions). It was decided to use the first 12 tasks and a multiple-choice format for this project. The 12 tasks of the schema which were used are:

1. Given the name of an attribute, select an example of the attribute.

2. Given an example of an attribute, select the name of the attribute.

3. Given the name of a concept, select an example of the concept.

4. Given the name of a concept, select a nonexample of the concept.

5. Given an example of a concept, select the name of the concept.

6. Given the name of a concept, select the relevant attribute.

7. Given the name of a concept, select the irrelevant attribute.

8. Given the definition of a concept, select the name of the concept.

9. Given the name of a concept, select the definition of the concept.

10. Given the name of a concept, select the supraordinate concept.

11. Given the name of a concept, select the subordinate concept.

12. Given the names of two concepts, select the relationship between them.

Single- or compound-word classificatory concepts (those that are defined by attributes) in science subject matter at the fourth grade level were identified. This task was subdivided into four steps:

1. Identifying the major areas within the subject matter of science,

2. Selecting three of these major areas to be studied,

3. Identifying classificatory concepts within each of these three major areas, and

4. Random sampling of ten concepts from those identified for each of the three major selected areas.

These procedures yielded a total of 30 science concepts for study. A list is given in Table 1, by area, of the concepts identified and randomly selected for study. The areas are Biological Science, Earth Science, and Physical Science. A description of the procedures used to identify these concepts can be found in "An Analysis of Selected Classificatory Science Concepts in Preparation for Writing Tests of Concept Attainment" (Voelker, Sorenson, & Frayer, 1971).

The researchers of Project 101, Situational Variables and Efficiency of Concept Learning, developed a system for analyzing a concept in preparation for developing items to measure the level of attainment of that concept (Frayer, Fredrick, & Klausmeier, 1969). Since the publication of that paper they, in cooperation with the researchers of the CAA Project, have refined their thinking and advanced this system. The refinements are discussed in "A Structure of Concept Attainment Abilities: The Problem and Strategies for Attacking It" (Harris, Harris, Frayer, & Quilling, in press). Briefly, a concept may be described in many ways: in terms of its criterial, relevant, and irrelevant attributes; its examples and nonexamples; its supraordinate, coordinate, and subordinate hierarchical relationships (theoretically determined); and its lawful or other types of relationships to other concepts. Knowledge of each of these kinds of information may be tested to determine a student's level of attainment of a concept. An analysis, along these lines, of each of the 30 sampled science concepts which are being studied can be found in "An Analysis of Selected Classificatory Science Concepts in Preparation for Writing Tests of Concept Attainment" (Voelker, Sorenson, & Frayer, 1971).

Thus, using the analysis of a concept as the basis for appropriate tasks, 12 items, one for each of the 12 tasks, could be developed for each of the 30 concepts making a total of 360 science items. A description of the procedures used in the development of these items, along with item and total score statistics (for concepts and for tasks) obtained for them for beginning sixth grade boys and girls can be found in "Measuring Science Concept Attainment of Elementary School Boys and Girls" (Voelker & Harris, in press). The items can be found in "Items for Measuring the Level of Attainment of Selected Classificatory Science Concepts by Intermediate Grade Children" (Voelker & Sorenson, 1971).

The study of the dimensionality of the two modes, concepts (content) and tasks, of this completely crossed design used to develop items to measure concept attainment in science will be discussed in the following sections.

Hypothesized Factor Structures

Alternative sets of factors were postulated for the science concepts and for the tasks using science content by viewing the concepts and the tasks as two independent modes. Viewing them in this way is essentially hypothesizing that no important interactions exist between the two modes.

Concepts

The most general hypothesis is that just

Table 1
Lists of Science Concepts by Topical Area

Biological Science	Earth Science	Physical Science
Adaptation	Air Pressure	Burning
Amphibian	Atmosphere	Condensation
Animal	*Cloud	*Conductor
*Bird	*Core	Contraction
Brain	Crust	Degree
*Cell	*Fossil	Dissolve
Eardrum	*Glacier	*Evaporation
Environment	Igneous rock	*Expansion
*Fish	Magma	Force
*Heart	Mantle	*Friction
Hibernate	Metamorphic rock	Fuel
*Invertebrate	*Meteor	Gas
*Lens - eye	Meteorite	*Liquid
Ligament	Mineral	Magnet
*Lungs	*Moon	Matter
*Mammal	Orbit	*Melting
*Muscle	*Planet	Molecular movement
Nervous system	Season	*Molecule
Optic nerve	*Sedimentary rock	Non-conductor
Plant	Solar system	*Solid
*Pore	Star	*Sound
Reptile	Sun	Temperature
Retina	*Volcano	*Thermometer
Sense	Weather	Work
Skeleton	*Wind	
Survival		
Vertebrate		
Water		

*Indicates that a test was developed and administered for this concept.

one common factor underlies the selected science concepts. Next in the order of generality to specificity is that three common factors are present, one for each of the three major areas selected for study: Biological Science, Earth Science, and Physical Science. A more specific hypothesis is that there may be two or more common factors for each of the three areas. A structure of the concepts within each of the three areas was not hypothesized. Instead, it was preferred to randomly sample concepts from each area and see what functional relationships exist among those sampled concepts. It was felt that this would eliminate bias in the picture of the dimensionality of the concepts imposed by theoretical relationships that may or may not exist in actuality. If attainment of concepts is highly specific, this approach may be detrimental as there may not be at least two measures (concepts) of a concept dimension included. There are some indications that the concepts are not this specific. For example, fairly reliable task scores obtained by totalling across the 30 concepts for a single task were obtained. This indicates some degree of homogeneity among the concepts.

Tasks

The most general hypothesis is that just one common factor or ability underlies the 12 tasks. A more specific hypothesis is that there are five underlying abilities: an ability dealing with attributes (Tasks 1 and 2), one dealing with examples of a concept (Tasks 3, 4, and 5), one related to the definition of a concept (Tasks 6, 7, 8, and 9),[1] one related

[1]A concept is defined in terms of its relevant attributes.

to hierarchical relationships (Tasks 10 and 11), and one for a relationship of a concept with another concept (Task 12). A somewhat more specific hypothesis is that there are six abilities: the five just listed, with the exception that the ability related to the definition of a concept may be further specific to those tasks dealing with relevant and irrelevant attributes (Tasks 6 and 7) and those tasks dealing directly with a definition (Tasks 8 and 9).

These alternative sets of factors represent an a priori analysis of the science concepts and the tasks when using science content. A major question to be answered in this study is the extent to which the obtained factors parallel such hypothesized analyses. Note that, as discussed, several levels of specificity are postulated. Another question to be answered in this study is the extent to which the concepts and the tasks are independent as hypothesized.

II
Procedures

Subjects

Pilot studies revealed that the selected concepts were very difficult for fourth graders. Thus, the decision was made to test fifth grade students on the concepts identified and sampled from the fourth grade textbooks. Items were administered during the fall of 1970 to 186 boys and 259 girls who were just beginning the sixth grade in the public school system of Madison, Wisconsin. The subjects were those students who volunteered to participate in response to a letter sent to random samples from the population of all such boys and from the population of all such girls. Approximately 60% of those invited to participate responded affirmatively. The subjects who completed the testing program were paid $7.50.

Since the participation of all students comprising the random sample was impossible to attain, test score and IQ data were obtained from the files of the Madison School System for both the school population and those participating students for whom the information was available. Table 2 includes the summary statistics for the population of fifth grade students in the public school system of the city of Madison during the school year 1969-70, and for the boys and the girls who comprised the tested samples for the science items. These data indicate that there was little difference between the volunteer group and the population. The IQ scores were obtained in the fall of 1968 when the subjects were fourth graders, and the scores on the Iowa Tests of Basic Skills, given in grade equivalent scores, were obtained in the fall of 1969 when the subjects were fifth graders.

Data on fathers' occupations were collected from the tested students using the Master Occupational Code of the United States Bureau of the Census. These data were tabulated and are presented in Table 3.

Data Collection

The data were collected during five 2-hour testing sessions from mid-October to early November. Since a large percentage of sixth graders attended one of three middle schools, it was decided to test the selected students from those schools in their own buildings after school hours. The sixth grade students attending various elementary schools were tested on three consecutive Saturday mornings at centrally located schools. Each 2-hour session consisted of a 72-item "test" composed of science items and a 71-item "test" composed of language arts items with an activity break between the two. The science and the language arts items were administered first on alternate days.

The 360 science items were arranged in five 72-item "tests," the order of assignment being random. Two different random orders were used to collect the data: one for each type of school (elementary and middle) for both boys and girls. The items were arranged in five test booklets according to the random order. The tests were given by experienced test administrators to groups of approximately 30 subjects each. The students responded to the items by marking their chosen response directly on an answer sheet. The answer sheets were read by machine and the responses punched onto data cards.

Treatment of the Data

The treatment of the data consisted of two main procedures: reliability estimation and factor analysis. The data were analyzed separately for each sample—boys and girls. Hoyt analysis of variance reliability estimates were obtained for each of the 30 concept scores and each of the 12 task scores for each group studied. Means and standard deviations for

Table 2
Mean Scores and Standard Deviations on
Lorge-Thorndike Intelligence Test and Iowa Tests of Basic Skills
for Students in Population and Samples

		Population	Boys	Girls
Lorge-Thorndike Intelligence	$\bar{X}$	106.6	106.11	112.23
	s		14.82	13.37
	N	2605	161	239
Iowa Basic Skills				
Vocabulary	$\bar{X}$	5.53	5.54	5.88
	s		1.41	1.33
	N	2520	181	246
Reading Comprehension	$\bar{X}$	5.44	5.29	5.97
	s		1.51	1.35
	N	2520	181	247
Language Skills	$\bar{X}$	5.24	5.04	5.82
	s		1.44	1.34
	N	2520	181	248
Work-Study Skills	$\bar{X}$	5.46	5.41	5.86
	s		1.30	1.18
	N	2520	181	248
Arithmetic Skills	$\bar{X}$	5.05	5.08	5.35
	s		.96	1.00
	N	2520	181	247
Composite	$\bar{X}$	5.35	5.27	5.77
	s		1.17	1.11
	N	2520	181	245

each of the scores were also computed.

Factor Analysis

Developing one item for each of the 12 tasks for each of the 30 selected concepts yields a 12 (tasks) by 30 (concepts) matrix consisting of the score for each of the 360 items, one for each cell of the matrix, for each individual to whom the items are administered. A completely crossed design exists and two types of total scores can be secured from this matrix: a total score for each of the 30 concepts (totalled across tasks) and a total score for each of the 12 tasks (totalled across concepts). Figure 1 is an illustration of such a matrix. Using this design to test concept attainment yields data of a three-dimensional type, if more than one concept and more than one task are included. The three dimensions are concepts, tasks, and individuals. The application of conventional factor analysis procedures to such data presents certain problems. As it has been used in the past, the researcher commonly collapses one dimension of the data, thereby losing information that is possibly very important. For example, common practice would be to use mean scores over the set of individuals to create a two-dimensional concept by task matrix which is then "factored."

Tucker's (1966a, 1966b) three-mode factor analysis has made it possible to factor analyze three-dimensional data without the potential loss of information involved in collapsing a dimension. There are some problems, however,

Table 3
Distribution of Fathers' Occupations for Students in the Samples

	Girls	Boys
00. Accountant	4	7
01. Architect	3	2
02. Dentist	3	1
03. Engineer	10	7
04. Lawyer, Judge	6	2
05. Clergyman	--	3
06. Doctor	12	3
07. Nurse	--	--
08. Teacher, Professor	20	15
09. Other professional	26	15
11. Farmer	--	--
21. Owner of business	4	2
22. Manager, Official	28	13
31. Bookkeeper	--	--
32. Receptionist	1	--
39. Other clerical	6	4
49. Salesman	27	24
51. Craftsman, Skilled worker	39	22
52. Foreman	--	2
53. Armed Services - officer	--	1
54. Armed Services - enlisted	--	1
61. Truck driver	5	4
62. Operative in factory	16	11
69. Other operative	12	12
71. Fireman	2	2
72. Policeman	2	4
73. Other protective service	3	--
74. Nurse's aide	1	1
75. Private household worker	--	--
79. Other service worker	14	16
81. Non-farm laborer	3	2
82. Farm laborer	1	--
91. Not presently in labor force	6	6
99. Not ascertained	12	10

in applying the analysis to data collected using the concept by task design with one item per cell. First, the data for a three-mode system are 0-1 data with a single item per cell; thus, there is a reliability problem with single item variables. Second, the common factors in the system are of major interest and the program to which there is access is for a component type analysis. Third, as in ordinary factor analysis, the question of the number of factors (components) to extract is a difficult question to answer, and this information has to be input into the three-mode program. For these reasons the procedures outlined here were used for factor analyzing the science data collected using the schema for testing level of concept attainment.

Briefly, the strategy consists of performing conventional factor analyses separately for the concepts and for the tasks to gain some insight into the interrelationships among the variables of a single mode. Tucker's three-mode factor analysis was then used to determine if there are any important concept-task interactions for the idealized persons (person factors).

Conventional Factor Analyses. The original plans called for determining the comparable common factors, separately for the concepts and for the tasks, by using a strategy suggested by Harris and Harris (1970). This strategy is a way to determine those factors

CONCEPTS

	Area: Biological Science 1 2 10	Area: Earth Science 11 12 20	Area: Physical Science 21 22 30	Total Score for Tasks
1				
2				
.				
TASKS .				
.				
.				
.				
12				
Total Score for Concepts				

Fig. 1. Item matrix for each individual.

that are robust with respect to method—factors which tend to include the same variables across methods. Analyses were obtained using three initial factor methods: Alpha (Kaiser & Caffrey, 1965), Harris R-S^2 (Harris, 1962), and Unrestricted Maximum Likelihood Factor Analysis (UMLFA) (Jöreskog, 1967). These three methods provide a factor solution with a statistical basis with the number of factors determined by a statistical test (UMLFA), and two factor solutions with a psychometric basis: one for a relatively small number of factors (Alpha) and one for a relatively large number of factors (Harris R-S^2). All three of the methods are independent of the scale of the variables. Derived orthogonal solutions were obtained for each of the three initial solutions using the Kaiser normal varimax procedure (Kaiser, 1958), and derived oblique solutions were obtained using the Harris-Kaiser independent cluster solution (Harris & Kaiser, 1964).

The "right number of factors" question is one for which there is still no definitive answer. For matrices which yield about the same number of factors when different methods are used, Harris and Harris (1970) suggest taking the comparable common factors as the substantive results. Doing this, the number of factors can be more or fewer than the number of factors for any single solution. This idea does not seem to be appropriate when the number of common factors obtained using different methods varies considerably, as is the case, for example, with the factoring of the science concepts: for boys and girls respectively, 1 each for Alpha, 8 and 7 for Harris R-S^2, and 2 and 3 for UMLFA for both the derived orthogonal and derived oblique solutions. (These results will be presented and discussed in detail in the next section.)

Alpha sometimes underfactors, and underfactoring is, according to Kaiser, "an unforgivable sin." Harris R-S^2 extracts a relatively large number of factors (Kaiser calls it deliberate overfactoring); but this is no problem since derived orthogonal common factors retain the important things, get rid of the "garbage," and are in no way substantially affected by doing so (Kaiser, 1970). As an example, for the science concepts, Harris R-S^2 extracted

17 factors initially for both the boys and the girls but the derived orthogonal solutions trimmed these to 8 common factors for boys and 7 for girls. Kaiser (1970) advocates this "deliberate overfactoring" but says he wishes oblique transformations were robust to it which they are not. This problem was "solved" by not submitting the initial raw factor matrix to oblique rotation. Instead, the common factors of the derived orthogonal solution were taken as F and used to build R^*. The Q obtained from a principal axes decomposition of R^* then was submitted for oblique transformation. Thus: derived orthogonal common factors = F: $FF' = R^*$; $R^* = QD^2Q'$; and then this Q is transformed to give an oblique solution. It may be pointed out here that getting derived oblique factors from the initial raw factor matrix or from the Q obtained from R^* will not make any difference if the number of initial factors and the number of derived orthogonal common factors is the same; this is the case for the factors obtained for the science concepts and tasks using both Alpha and UMLFA. Incidentally, Kaiser (1970) in the same paper advocates obtaining "Harris factors" as they are model-free. What is named Harris $R-S^2$ is one of the set of "Harris factors."

Discussion of the number of factors is important since it is necessary to input the number of factors for concepts and the number of factors for tasks into the three-mode program. For these science data the number of factors used was the number of Harris $R-S^2$ derived oblique common factors for the concepts and the number of UMLFA derived oblique common factors for the tasks. The main reason for this is that these solutions give as many or more common factors as the other two solutions and greater specificity should allow any concept-task interactions to be more demonstrable.

Three-Mode Factor Analyses. As was mentioned earlier in the paper, three-mode factor analyses (Tucker, 1966a, 1966b) were performed to determine if there are any important concept-task interactions for the idealized persons. Three problems were mentioned at that time. Two of them were "solved" by doing the conventional factor analyses. The common factors in each of the two modes, concepts and tasks, were obtained and the number of factors (components) to input into the three-mode program for the two modes other than individuals was determined. The third problem still remains—the reliability problem with single item variables consisting of 0-1 type data. To alleviate this problem, a three-mode analysis was performed on two different forms of the same data in an attempt to gain insight into the existence of any important concept-task interactions. It might also be pointed out that the existing program has the capacity to handle only a product of 120 for the two modes other than individuals. Thus, we could not analyse our 30 concepts by 12 tasks, as this gives a product of 360. It would have been possible to expand the program's capacity to some extent, but it would have been very difficult, it not impossible, to expand it to handle a product of 360.

Conceptually, the 30 concepts were organized into three areas within the subject matter field. This categorization was done by subject matter experts. A three-mode analysis was conducted using only three variables for concepts. Each of these variables is a composite of the items for a single task across the ten concepts within a single area. Thus, the input data for this analysis consisted of a 3 (concepts) by 12 (tasks) matrix of 36 entries for each individual. Each entry consisted of the total number correct of ten items. The number of factors (components) for concepts input for this analysis was taken as three. The number of factors (components) for tasks input for this analysis was the number of derived oblique factors obtained for the UMLFA method—three for both boys and girls. This analysis will be referred to as Type I three-mode analysis. Such an analysis should permit any task interactions to be clearly evident, as each task is a separate entry; actually each task comprises three separate entries, one for each composite concept variable.

A second three-mode analysis, to be referred to as Type II, was conducted using all 30 of the concepts but only three task variables. The task variables are composites of the items for a single concept for given tasks. The composites formed for boys are:

Task Variable A - Tasks 1, 2, and 4
Task Variable B - Tasks 3 and 5
Task Variable C - Tasks 6, 7, 8, 9, 10, 11, and 12

The composites formed for girls are:

Task Variable A - Tasks 1, 2, and 5
Task Variable B - Tasks 3 and 4
Task Variable C - Tasks 6, 7, 8, 9, 10, 11, and 12

The formation of the composites was based on the derived oblique factors obtained for the UMLFA method. A task was assigned to a composite on the basis of its highest factor coefficient. It is realized that this is essentially forming factor scores using a rather undesirable method, but it was felt that since the intercorrelations of the task factors are very high (in fact so high that a reasonable interpretation is that the 12 tasks are all measures of the same latent ability), it would not be too detrimental. Also, it provided a way of forming composites based on experimental results rather than theoretical considerations to allow for greater specificity; an alternative would have been to input only one variable for tasks which would consist of a composite for all 12 of the tasks. Thus, the input data for this Type II three-mode analysis consisted of a 30 (concepts) by 3 (tasks) matrix of 90 entries for each individual. Each entry consisted of the total number answered correctly for one of the three composite task variables consisting of three, two, and seven items respectively. The number of factors (components) for tasks input for this analysis was taken as three. The number of factors (components) for concepts input for this analysis was the number of derived oblique factors obtained for the Harris $R\text{-}S^2$ method—eight for boys and seven for girls. Such an analysis should permit any concept interactions to be clearly evident since each concept is a separate entry; actually, each concept comprised three separate entries, one for each composite task variable. There still may be somewhat of an unreliability problem in this analysis, as some of the entries consist of the total score for just two items.

The results of treating the data in these various ways are presented and discussed in the following section.

III
Results and Discussion

The means, standard deviations, and Hoyt reliability estimates obtained for the data collected during summer and fall of 1970 using the science items developed are presented, separately for boys and girls, for total concept and total task scores. The intercorrelations and factor results for these data are presented and discussed, once again separately for boys and girls.

Reliability Estimates and Test Statistics

Tables 4 and 5 contain the means, standard deviations, and Hoyt reliability estimates obtained for the data collected during fall, 1970, using the revised items for total concept and total task scores. The data were analyzed separately for the 186 boys and the 259 girls. The concept scores consist of 12 items each, and the task scores of 30 items each.

The mean scores for concepts are generally slightly higher for girls than they are for boys; girls attained a higher mean score for 25 of the 30 concepts, but the difference approached one score point, which is less than one-half of a standard deviation, for only one of the concepts. The mean scores for tasks are also slightly higher for girls than for boys; girls attained higher mean scores than the boys for all 12 of the tasks. These differences are generally less than one-fourth of a standard deviation.

The reliability estimates are generally slightly higher for boys than for girls. For the task scores they are in the .80s for boys with the exception of one which is .76, and in the .70s and .80s for girls with the exception of one which is .66. For the concept scores the reliability estimates are in the .60s and .70s for boys and the .50s to .70s for girls. It is to be expected that the task scores are more reliable than the concept scores since the task scores are based on 30 items while the concept scores are based on only 12 items.

The reliability estimates are sufficiently high to warrant study of the dimensionality of these selected science concepts and the tasks when using science content. This is a major objective of the CAA Project and is the main purpose for developing these items to measure science concept attainment.

Factor Analyses

The correlation matrices for the concept scores upon which the factor analyses were based are given in Table 6 for boys and Table 7 for girls. The intercorrelations for the task scores are given in Table 8 for boys and Table 9 for girls.

The intercorrelations of the concept scores are quite consistent in magnitude within the matrix for both boys and girls. The correlations are in the .50s to mid .70s for boys and the .40s to low .70s for girls. The reliability estimates obtained for the concept scores range from .60 to .79 for boys and from .52 to .78 for girls. Thus, if the correlations were corrected for attenuation they would all be quite high. The lower correlations obtained are almost wholly associated with the concept scores which have low reliability estimates.

The intercorrelations of the task scores are quite consistent in magnitude for boys and girls. They are in the .70s and .80s for both boys and girls with a few in the .60s which are almost entirely for Task 4. Once again, it is interesting to look at the reliability estimates for the task scores. They are in the .80s for boys and the .70s and .80s for girls with the exception that the reliability estimate for Task 4 is .76 for boys and .66 for girls. Thus,

Table 4
Means, Standard Deviations, and Hoyt Reliabilities for Tests of Concept Attainment—Science

Concept	Mean		Standard Deviation		Hoyt Reliability	
	Boys	Girls	Boys	Girls	Boys	Girls
1. Bird	8.88	9.43	2.20	1.88	.62	.55
2. Cell	7.33	7.29	2.50	2.28	.61	.54
3. Fish	9.42	10.08	2.30	1.86	.71	.65
4. Heart (Human)	8.79	9.36	2.63	2.39	.74	.72
5. Invertebrate	7.40	7.42	2.79	2.63	.73	.69
6. Lens (Eye)	7.87	8.08	2.47	2.19	.68	.60
7. Lungs	8.95	9.45	2.82	2.61	.79	.78
8. Mammal	9.61	10.44	2.48	2.11	.76	.76
9. Muscle	8.07	7.99	2.52	2.69	.67	.70
10. Pore (Skin)	8.26	8.85	2.68	2.73	.72	.77
11. Cloud	8.22	8.67	2.58	2.03	.72	.58
12. Core (Earth)	8.68	8.99	2.66	2.22	.75	.66
13. Fossil	8.81	9.36	2.46	2.08	.70	.62
14. Glacier	8.32	8.69	2.48	2.41	.66	.67
15. Meteor	7.65	7.67	2.76	2.43	.72	.64
16. Moon	8.57	8.34	2.76	2.85	.76	.78
17. Planet	8.32	8.67	2.43	2.36	.68	.68
18. Sedimentary Rock	7.91	8.75	2.68	2.50	.71	.72
19. Volcano	8.78	9.27	2.33	2.08	.65	.60
20. Wind	8.76	9.56	2.56	2.19	.71	.67
21. Conductor	6.62	6.04	2.73	2.60	.68	.66
22. Evaporation	7.99	8.29	2.71	2.53	.71	.67
23. Expansion	7.51	7.80	2.74	2.77	.71	.73
24. Friction	7.69	7.49	2.35	2.16	.62	.52
25. Liquid	8.89	9.22	2.35	2.29	.67	.68
26. Melting	7.75	8.37	2.40	2.16	.65	.62
27. Molecule	6.62	6.99	2.48	2.33	.60	.56
28. Solid	8.58	9.56	2.76	2.21	.77	.69
29. Sound	8.16	8.54	2.49	2.27	.69	.66
30. Thermometer	8.34	8.68	2.54	2.07	.71	.57

Table 5
Means, Standard Deviations, and Hoyt Reliabilities for Tests of Task Attainment—Science

Task Number[a]	Mean		Standard Deviation		Hoyt Reliability	
	Boys	Girls	Boys	Girls	Boys	Girls
1	23.17	24.54	5.14	4.51	.84	.83
2	22.22	23.44	5.74	4.80	.87	.84
3	23.50	24.11	4.46	3.60	.80	.72
4	23.34	23.65	4.20	3.38	.76	.66
5	22.95	23.57	5.36	4.30	.85	.78
6	18.76	20.18	6.10	5.61	.85	.83
7	16.76	18.05	6.30	5.74	.85	.83
8	20.17	21.37	6.81	5.76	.89	.85
9	19.06	20.26	6.48	5.99	.87	.86
10	20.67	21.04	6.50	5.94	.88	.87
11	18.82	19.49	5.66	4.81	.83	.77
12	17.32	17.63	5.90	5.52	.83	.81

[a]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 nonexample 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 definition of concept, select name of concept.
9. Given name of concept, select definition of concept.
10. Given name of concept, select supraordinate concept.
11. Given name of concept, select subordinate concept.
12. Given names of two concepts, select principle relating them.

Table 6
Intercorrelations of Science Concepts: Boys[a]

Concept	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
2	59																												
3	65	56																											
4	65	59	69																										
5	58	53	65	62																									
6	59	62	64	67	56																								
7	68	55	76	76	66	66																							
8	60	51	67	64	63	59	68																						
9	61	61	66	70	63	66	70	59																					
10	64	62	67	72	61	56	75	63	69																				
11	64	63	69	71	61	65	74	67	70	71																			
12	56	61	71	69	63	57	69	62	72	71	67																		
13	66	59	72	71	62	60	75	66	64	66	73	67																	
14	66	61	69	68	56	53	74	66	63	69	69	65	71																
15	55	59	62	69	59	65	66	55	66	65	69	63	71	62															
16	63	63	61	62	59	60	66	60	66	66	71	61	66	66	70														
17	64	59	69	70	59	63	68	68	67	68	69	68	66	68	67	70													
18	61	62	65	64	55	61	61	55	62	59	61	58	66	61	59	61	62												
19	68	57	73	74	61	66	74	67	70	71	74	61	70	69	63	68	67	66											
20	67	64	75	71	62	60	70	70	68	73	75	71	71	71	66	70	72	62	71										
21	56	61	56	59	51	59	58	50	56	61	63	50	49	56	60	58	60	58	57	58									
22	62	63	62	70	60	65	69	59	67	72	70	68	69	62	67	67	72	58	67	66	61								
23	63	60	60	68	58	62	68	64	64	70	75	64	62	65	63	66	68	60	66	68	65	72							
24	54	63	64	63	62	59	60	60	63	63	64	61	61	56	62	63	67	59	61	61	58	62	63						
25	55	59	61	64	56	57	66	62	62	67	66	65	63	59	60	61	64	58	64	64	52	63	67	62					
26	63	56	64	69	56	64	71	61	68	65	71	68	68	68	66	68	68	61	69	65	52	72	66	61	65				
27	56	58	53	64	54	61	63	52	65	59	64	58	53	56	59	65	59	54	62	58	56	66	64	54	58	61			
28	65	62	69	64	57	58	71	67	61	70	72	64	70	72	64	67	71	64	68	71	60	69	72	59	68	67	62		
29	60	60	67	72	58	65	70	62	62	63	68	66	69	66	71	64	68	57	65	64	60	68	65	59	63	68	59	63	
30	63	60	71	70	54	64	69	64	69	68	69	68	69	66	63	68	68	61	71	69	54	66	67	62	64	65	54	68	67

[a]Decimals have been omitted.

Table 7
Intercorrelations of Science Concepts: Girls[a]

Concept	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
2	42																												
3	58	45																											
4	50	54	67																										
5	46	44	53	54																									
6	38	43	53	49	40																								
7	54	50	68	73	60	55																							
8	58	51	66	59	51	51	62																						
9	44	54	50	60	50	49	62	53																					
10	55	44	61	60	54	51	72	61	58																				
11	57	51	60	58	54	47	64	61	56	64																			
12	48	47	60	58	48	52	62	56	52	64	63																		
13	62	50	65	64	55	49	63	62	54	60	60	55																	
14	52	44	62	59	50	51	65	58	57	63	63	58	62																
15	55	60	58	61	55	49	62	56	60	61	64	55	65	55															
16	54	57	56	59	53	48	65	59	62	62	65	57	61	60	70														
17	51	48	63	61	54	53	69	61	60	62	66	60	63	61	64	70													
18	47	43	56	51	45	51	63	55	45	58	56	55	49	53	48	54	58												
19	51	51	58	62	51	51	66	60	57	59	61	54	66	56	64	58	65	55											
20	56	46	66	68	49	51	70	64	56	62	61	62	60	62	58	62	62	56	57										
21	47	49	46	48	45	45	52	43	50	50	53	41	52	48	52	57	52	47	49	44									
22	55	57	64	59	53	47	65	59	59	64	64	60	61	62	63	71	68	56	57	61	57								
23	53	48	61	59	51	51	65	57	57	70	61	56	66	59	61	64	68	51	61	58	54	64							
24	48	53	55	54	45	43	58	50	49	60	56	55	58	51	56	60	64	50	54	50	52	64	65						
25	52	52	65	59	50	51	68	61	58	66	64	62	65	63	62	67	64	55	58	62	53	62	64	62					
26	46	50	59	59	52	50	64	58	54	58	63	59	61	58	60	62	63	56	58	64	57	64	62	58	62				
27	43	42	49	53	49	38	55	44	51	54	54	47	50	52	51	48	52	46	51	50	45	58	53	42	52	51			
28	52	52	61	62	54	47	65	58	56	65	63	64	63	61	57	62	60	54	56	62	49	65	62	59	62	67	54		
29	61	53	65	64	52	45	62	66	56	61	66	58	70	61	64	61	63	50	56	60	51	62	64	60	63	65	52	67	
30	44	40	56	57	44	49	55	56	50	59	58	50	55	56	52	53	59	49	51	57	47	56	58	54	58	60	42	57	59

[a]Decimals have been omitted.

Table 8
Intercorrelations of Science Tasks: Boys[a]

Task	1	2	3	4	5	6	7	8	9	10	11
2	88										
3	80	79									
4	72	75	73								
5	83	86	86	74							
6	77	79	70	71	76						
7	75	79	67	64	72	84					
8	82	86	76	70	83	86	81				
9	78	82	72	70	80	89	83	89			
10	83	84	77	72	83	84	82	87	86		
11	80	82	72	68	81	85	80	86	86	83	
12	72	76	66	67	71	83	80	82	85	79	80

[a]Decimals have been omitted.

Table 9
Intercorrelations of Science Tasks: Girls[a]

Task	1	2	3	4	5	6	7	8	9	10	11
2	82										
3	76	79									
4	66	73	76								
5	76	81	80	75							
6	77	78	71	62	73						
7	74	71	69	56	66	80					
8	82	82	74	66	76	83	75				
9	81	80	77	69	77	84	80	87			
10	79	80	76	70	77	83	76	86	86		
11	74	76	72	67	72	79	75	82	84	82	
12	73	72	71	62	71	79	77	78	82	81	78

[a]Decimals have been omitted.

as with the concepts, if the correlations were corrected for attenuation, they would almost all be extremely high. The uncorrected correlations are all quite high.

Conventional Factor Analyses

The numbers of factors obtained for the initial solutions and for the derived solutions, orthogonal and oblique, are given in Tables 10 and 11 according to the numbers of common, specific, and null factors. A common factor is defined as one having at least two variables with coefficients greater than .30 (absolute).[2] A specific factor has only one coefficient greater than .30 (absolute), and a null factor does not have any coefficients greater than .30 (absolute). The factors rotated for the derived oblique solutions were the orthogonal common factors obtained for that method. For this purpose a common factor was defined as one having at least two variables with coefficients greater than .300 (absolute).[3]

[2]After rounding to two places.
[3]After rounding to three places.

Table 10
Numbers of Initial and Derived Factors for Concept Scores: Boys and Girls

Factor Method	Initial Factors B	Initial Factors G	Derived Orthogonal Factors: Common B	Common G	Specific B	Specific G	Null B	Null G	Derived Oblique Factors: Common B	Common G	Specific B	Specific G	Null B	Null G
Alpha	1	1	1	1	0	0	0	0	1	1	0	0	0	0
Harris R-S^2	17	17	8	7	1	2	8	8	8	7	0	0	0	0
UMLFA	2	3	2	3	0	0	0	0	2	3	0	0	0	0

Table 11
Numbers of Initial and Derived Factors for Task Scores: Boys and Girls

Factor Method	Initial Factors B	Initial Factors G	Derived Orthogonal Factors: Common B	Common G	Specific B	Specific G	Null B	Null G	Derived Oblique Factors: Common B	Common G	Specific B	Specific G	Null B	Null G
Alpha	1	1	1	1	0	0	0	0	1	1	0	0	0	0
Harris R-S^2	5	4	2	2	0	1	3	1	2	2	0	0	0	0
UMLFA	3	3	3	3	0	0	0	0	3	3	0	0	0	0

The derived orthogonal common factor results can be found in Appendices A-D; the derived oblique common factor results are presented in Tables 12-15. Only coefficients greater than .30 (absolute) are included. The order of the factors for each solution is arbitrary. The intercorrelations of the factors are included in the tables for the oblique solutions.

Interpretation of Factor Results for Concept Scores. The factor results for the concepts can be interpreted at two levels. One of these is the general level. The most reasonable interpretation is that all 30 of the concepts are measures of a single functional relationship existing among the concepts; this holds for both boys and girls. At least four things lead to such an interpretation. First, the intercorrelations of the 30 concepts are all quite uniform. They would probably fit a Spearman pattern fairly well; this indicates a single common factor. The correlations, if corrected for attenuation, would all be quite high. The eigenvalues of the correlation matrices obtained for both boys and girls are characterized by the first one being very large followed by a great drop in magnitude to the next ones which diminish very gradually. Finally, the oblique factor intercorrelations are uniformly extremely high, indicating only one second-order factor. Such an interpretation is reasonable in terms of past studies, also. In the literature for factor studies that include measures of achievement, the results typically indicate that achievement measures are found on a single factor. We have here achievement measures for a single subject matter field which, conceptually at least, should be even more closely related than achievement measures from several different areas of study.

The other level at which the factor results can be interpreted is a more specific one. The derived orthogonal factors are not very meaningful; they are not very interpretable psychologically. As can be seen from Tables 12 and 13, the oblique factors are very highly correlated; thus, imposing the restriction of orthogonality on the factors for these sets of data gives results that are not very meaningful. Many of the variables are of complexity 2, 3, and even higher in the orthogonal solutions. For example, for the two factors of the UMLFA solution for boys, all of the concepts have coefficients greater than .30 on both of the factors; for the girls, 21 of the concept variables are of complexity 3 for the three factors of the UMLFA solution. Even for the greater number of factors

Table 12
Oblique Common Factor Results for Science Concepts: Boys[a]

	Alpha	Harris R-S[2]								UMLFA	
Concept	A-1	H-1	H-2	H-3	H-4	H-5	H-6	H-7	H-8	U-1	U-2
Area: Biological Science											
1 Bird	77	93								63	
2 Cell	74			65							97
3 Fish	82	46	50			-34				131	-47
4 Heart	84		42							54	32
5 Invertebrate	73							75		60	
6 Lens	77	-36	109								73
7 Lungs	86	63								94	
8 Mammal	77	37							62	96	
9 Muscle	82		47		56						58
10 Pore	83	43			41					45	40
Area: Earth Science											
11 Cloud	86	31							33	33	54
12 Core	80				99					60	
13 Fossil	83	52					64			99	
14 Glacier	81	115	-32							92	
15 Meteor	80						96				72
16 Moon	81	33									77
17 Planet	83									37	47
18 Sedimentary Rock	75		45	31						39	36
19 Volcano	84	50	75							74	
20 Wind	84	72			32					80	
Area: Physical Science											
21 Conductor	71			67						-33	105
22 Evaporation	83										98
23 Expansion	82								83		95
24 Friction	76	-54						37	57		64
25 Liquid	77								108		53
26 Melting	81										52
27 Molecule	74					60				-40	115
28 Solid	83	67							65	49	35
29 Sound	81						73			34	48
30 Thermometer	81		63		31			-35	39	66	
Intercorrelations of factors	2	93								95	
	3	81	84								
	4	91	91	79							
	5	75	79	78	75						
	6	91	92	82	90	79					
	7	86	88	76	87	68	84				
	8	95	93	86	92	80	92	87			

[a]Includes those variables which have coefficients greater than .30 (absolute).
Decimals have been omitted.

Table 13
Oblique Common Factor Results for Science Concepts: Girls[a]

	Alpha	Harris R-S[2]							UMLFA		
Concept	A-1	H-1	H-2	H-3	H-4	H-5	H-6	H-7	U-1	U-2	U-3
Area: Biological Science											
1 Bird	68			109							84
2 Cell	65		82							86	
3 Fish	78			52				40	75	-43	49
4 Heart	78							96	74		
5 Invertebrate	67					51					
6 Lens	64	97							79		
7 Lungs	84	32						62	116		
8 Mammal	76	40		66					44		58
9 Muscle	72		37			33			33	62	
10 Pore	80				50	39			74		
Area: Earth Science											
11 Cloud	80					39	41	-32		39	
12 Core	74	50							75		
13 Fossil	80			70							85
14 Glacier	76					35			63		
15 Meteor	78		50							76	
16 Moon	80		41		37					98	
17 Planet	81				52				37	56	
18 Sedimentary Rock	69	87							90		
19 Volcano	76								38		
20 Wind	78							53	100		
Area: Physical Science											
21 Conductor	66		32							90	
22 Evaporation	81				38	31				73	
23 Expansion	79				81					52	
24 Friction	73				107					74	
25 Liquid	80				38				41	32	
26 Melting	78						91			39	
27 Molecule	65					100			35	33	
28 Solid	79						63		37		
29 Sound	80	-40		58			56				97
30 Thermometer	70						76		40		

Intercorrelations of factors		Harris						UMLFA	
	2	80						93	
	3	89	82					92	91
	4	90	85	90					
	5	90	84	89	91				
	6	92	83	92	93	91			
	7	92	80	90	87	90	90		

[a]Includes those variables which have coefficients greater than .30 (absolute). Decimals have been omitted.

Table 14
Oblique Common Factor Results for Science Tasks: Boys[a]

Task	Alpha A-1	Harris R-S² H-1	H-2	UMLFA U-1	U-2	U-3
1 Given name of attribute, select example.	89	79		120		
2 Given example of attribute, select name.	92	72		69		
3 Given name of concept, select example.	83	112		46	54	
4 Given name of concept, select nonexample.	79	74		39		
5 Given example of concept, select name.	90	97			116	
6 Given concept, select relevant attribute.	91		102			105
7 Given concept, select irrelevant attribute.	87		98			93
8 Given definition of concept, select name.	93		75			78
9 Given name of concept, select definition.	92		99			105
10 Given concept, select supraordinate concept.	93	34	60			61
11 Given concept, select subordinate concept.	91		77			76
12 Given two concepts, select relationship.	86		106			108
Intercorrelations of factors: 2		91		91		
3				93	87	

[a]Includes those variables which have coefficients greater than .30 (absolute). Decimals have been omitted.

Table 15
Oblique Common Factor Results for Science Tasks: Girls[a]

Task	Alpha A-1	Harris R-S² H-1	H-2	UMLFA U-1	U-2	U-3
1 Given name of attribute, select example.	88	35	51	102		
2 Given example of attribute, select name.	89	63		101		
3 Given name of concept, select example.	86	85		37	53	
4 Given name of concept, select nonexample.	77	103			96	
5 Given example of concept, select name.	86	84		52	44	
6 Given concept, select relevant attribute.	89		99			79
7 Given concept, select irrelevant attribute.	83		106			90
8 Given definition of concept, select name.	91		82	49		56
9 Given name of concept, select definition.	93		87			87
10 Given concept, select supraordinate concept.	92		78			80
11 Given concept, select subordinate concept.	88		81			94
12 Given two concepts, select relationship.	86		96			107
Intercorrelations of factors: 2		91		90		
3				94	83	

[a]Includes those variables which have coefficients greater than .30 (absolute). Decimals have been omitted.

for the Harris R-S^2 solutions, there are still a large number of concept variables of complexity 2, 3, 4, and even 5. Thus, at a more specific level, it makes sense to interpret only the oblique solutions. It must be remembered, however, that the correlations of these factors are all extremely high.

For matrices which yield about the same number of factors when different methods are used, Harris and Harris (1970) suggest taking the comparable common factors, those that are robust over method, as the substantive results. This idea does not seem to be appropriate when the number of common factors obtained using different methods varies considerably, as is the case with the factoring of these science concepts: for boys and girls respectively, 1 each for Alpha, 8 and 7 for Harris R-S^2, and 2 and 3 for UMLFA. Thus, it seems the only appropriate thing is to look at the results for each method individually.

The results for the boys are given in Table 12. For these science concepts, Alpha yielded just one common factor. The coefficients on this factor are all quite uniform for the 30 concepts.

The UMLFA method yielded two common factors, but they are correlated .95 which makes it academic to place any emphasis on the distinctions between the two. There is really no good rationale for explaining them. One could say that U-1 is associated mainly with the concepts from the two areas Biological Science and Earth Science, and that U-2 is associated mainly with the concepts from the area of Physical Science. These distinctions are not really very clear, however, as ten of the variables are of complexity 2 and each of the two factors includes some concepts from each of the three areas.

The Harris R-S^2 solution is, in general, much more difficult to interpret than the others. Even with the greater number of factors and the relatively small number of variables on each of the factors, the factors are still moderately to extremely highly correlated. Adding to the difficulty of the interpretation is the fact that 14 of the concept variables are of complexity 2, 3, and 4. Of these 14, 5 are bipolar. All of this seems to add credence to the interpretation of a single functional relationship existing among the 30 concepts studied. H-1 is the most general of the Harris R-S^2 factors including five concepts from Biological Science, six from Earth Science, and one from Physical Science. In addition, there are two negative coefficients. There appears to be no apparent explanation for this factor. It includes a rather odd assortment of concepts and a "more-less familiar" interpretation does not seem to be justified either. There seems to be no rationale for explaining H-2 which includes Lens, Volcano, Thermometer, Fish, Muscle, Sedimentary Rock, and Heart. H-3 is comprised mainly of the two concepts Conductor and Cell. Core, Muscle, and Pore are the main concepts appearing on H-4; Wind and Thermometer have small coefficients on this factor. H-5 is essentially a specific for the concept Molecule. The three concepts Meteor, Sound, and Fossil appear on H-6. H-7 is essentially a specific for the concept Invertebrate. Liquid, Expansion, Solid, and Friction are four concepts from Physical Science with a logical relationship, but it is curious why Mammal should appear with them on H-8. Also appearing on H-8 but with much smaller coefficients are Thermometer and Cloud.

The results for the girls interpreted here are given in Table 13. As with the boys, Alpha yielded just one common factor.

The UMLFA method yielded three factors for girls as compared to two for boys. The intercorrelations of these three factors are in the low .90s. U-1 and U-2 are similar to the two factors of the UMLFA solution for boys. U-1 includes many of the Biological Science and Earth Science concepts and a few concepts, with smaller coefficients, from the area of Physical Science; U-2 includes many of the Physical Science concepts with Moon, Meteor, Planet, and Cloud from Earth Science and Cell and Muscle from Biological Science also appearing on U-2. U-3 is rather curious. Four of the five concepts appearing on it have a logical explanation; Bird, Mammal, and Fish are the three kinds of living creatures studied and they all can form Fossils. There is no explanation for Sound appearing with these four concepts, however. It should also be noted that the highest coefficient is for the concept Sound.

As with the boys, Harris R-S^2 results are much more difficult to interpret than the others. For the girls, only 9 of the 30 concept variables are of complexity 2 or 3 but the intercorrelations of the factors are quite high. H-1 includes Lens, Sedimentary Rock, Core, Mammal, and Lungs with Sound being negative. Cell, Meteor, Moon, Muscle, and Conductor are the variables appearing on H-2. H-3 is similar to U-3; the concepts appearing on it are the three kinds of creatures studied—Bird, Mammal, and Fish—Fossil, and Sound. Friction, Expansion, Planet, and Pore are the main concepts appearing on H-4 with Evaporation, Liquid, and Moon appearing with small coefficients. H-5 is essentially a specific for Molecule or a doublet for Moleclue and Invertebrate. Five other concepts appear on H-5 but with much smaller coefficients. Melting, Thermometer, Solid, Sound, and Cloud are the concept variables appearing on H-6. With the exception of Sound, these concepts are logically related. H-7 includes the concepts Heart, Lungs, Wind, and Fish with Cloud appearing with a small negative coefficient.

It is evident from the factor results that the three area distinctions are not clear functional distinctions; thus, the hypothesis that science concepts are functionally related according to these three conceptually-determined major content areas should be rejected.

A word of caution. Too much emphasis should not be placed on the distinctions just discussed, as the intercorrelations of the factors are extremely high. The two factors of the UMLFA solution for boys are correlated .95. As one would expect, as the results become more specific (more factors) the factors are less correlated. However, for the seven and eight factors of the Harris $R\text{-}S^2$ solution the correlations are in the .80s and .90s for girls and the .70s to .90s for boys; these correlations are very high, especially considering that there are very few variables on many of the factors.

It may be well to insert a reminder here that the orthogonal solutions are not very meaningful psychologically, since the complexity is greater than 1 for most of the concepts; most of the concepts appear on more than one factor.

Further interesting aspects of studying these science concepts are yet to come—the study of the relationships of selected science concepts with selected concepts from the other three subject matter fields being studied (language arts, mathematics, and social studies). This is Step 4 of the objectives of the CAA Project as stated on page 1.

Interpretation of Factor Results for Task Scores. As with the concepts, the factor results for the tasks can be interpreted at two levels. One level is a general one; all 12 of the tasks are measures of a single underlying ability or latent trait. This seems to be the most reasonable interpretation for the tasks since the intercorrelations of the oblique factors are extremely high when more than one factor is yielded. All of the reasons for a general interpretation for the concepts apply for the interpretation of the tasks: (a) the intercorrelations are all quite high and quite uniform—they would fit a Spearman pattern fairly well, (b) the correlations corrected for attenuation would all be extremely high, (c) the eigenvalues of the correlation matrices are characterized by the first one being very large followed by a great drop in magnitude to the next ones, and (d) the factor intercorrelations are uniformly very high, indicating only one second-order factor.

At a more specific level, only the oblique factor results are psychologically meaningful. These results are given in Table 14 for boys and Table 15 for girls.

The oblique factor results for the science tasks are essentially the same for both boys and girls. Alpha yielded only one common factor. Harris $R\text{-}S^2$ yielded two factors which are correlated .91 for both boys and girls. H-1 includes Tasks 1 through 5 and H-2 includes Tasks 6 through 12. (Note that Task 1 has a higher coefficient on H-2 for girls than it does on H-1.) Tasks 1 through 5 all deal with examples of a concept. Tasks 3, 4, and 5 deal with examples, and nonexamples, of the selected concept, while Tasks 1 and 2 deal with examples of an attribute of the selected concept which is, in itself, a concept. Tasks 6 through 12 deal with other, perhaps more difficult, aspects of a concept such as relevant and irrelevant attributes, definition, supraordinate and subordinate concepts, and a relationship with another concept.

Even though the UMLFA solution yielded three factors for both boys and girls, it is very similar to the Harris $R\text{-}S^2$ solution. U-3 is the same as H-2 including Tasks 6 through 12. The UMLFA solutions separate the five tasks appearing on H-1. For the Boys U-1 includes Tasks 1 through 4 and U-2 includes Tasks 3 and 5. Note that Task 3 is of complexity 2. For the girls U-1 includes Tasks 1, 2, 3, and 5 and U-2 includes Tasks 3, 4, and 5. Note that Tasks 3 and 5 are of complexity 2 for the girls. A three-factor solution for UMLFA is presented here; however, a two-factor solution may be a better one. A critical value of .05 was used to determine the number of factors for the UMLFA method. The critical values obtained for a two-factor solution were .03 and .02 for boys and girls, respectively. The critical values obtained for a three-factor solution were .66 for boys and .31 for girls. Tucker (1970) has shown, for a number of different matrices, that a critical value of .05 probably gives too many factors when there are about 200 subjects; fewer factors can provide a highly reasonable interpretation.

It must be remembered that the correlations of these task factors, when more than one is yielded, are in the .90s with the exception of U-2 and U-3 which are correlated .87 and .83 for boys and girls, respectively. Thus, not much if any emphasis should be placed on these distinctions just discussed. The most defensible interpretation is that there is a single common factor for these 12 tasks.

As with the concepts, a further interesting aspect of studying these tasks using science content will be to see how they are related to these same tasks when language arts, mathematics, and social studies concepts are employed as content.

GPO 887-870-4

Three-Mode Factor Analyses

As was discussed earlier, a three-mode factor analysis was performed on two different forms of the same data to gain insight into the existence of any important concept-task interactions for the idealized persons. Performing conventional factor analyses on the two modes, concepts and tasks, separately is essentially hypothesizing that there are no interactions. The three-mode analyses were performed to determine whether this hypothesis is a tenable one.

The Type I three-mode analysis is the analysis of the 12 tasks and the three composite concept variables; Type II is the analysis of the three composite task variables and the 30 concepts. Type I was performed to permit maximum task interactions to be evident; Type II to permit maximum concept interactions.

The core matrix obtained for each analysis is the only piece of the three-mode analysis of interest here since it contains the idealized person components by task components by concept components. Hence, it is in this matrix that any interactions are seen. The core matrices obtained for Type I and Type II analyses are presented in Table 16 for boys and in Table 17 for girls. Only those idealized person (core) components that have one or more coefficients greater than .50 (absolute) are included in the tables; the number of core components obtained in each of the analyses was equal to the product of the number of components for the two modes other than individuals. The variables comprising the task components are given in footnotes on each of the tables. The variables comprising the Type I concept components are the ten concepts in each of the three areas. The concept components for the Type II analyses bear little resemblance to the Harris R-S^2 factors which were the basis for the number of components to be extracted; the concept components obtained are much more specific. Most of them have only two or three variables with coefficients greater than .30 (absolute). These differences are not surprising or critical since the oblique factors are extremely highly correlated.

Both Type I and Type II analyses for the boys indicate that there is only one idealized person type—there is just one major core component. As indicated by the Type I analysis, persons respond similarly to the concepts of the three different areas; the Type II analysis indicates some slight differentiation among the concepts. For the Type I analysis, a person who scores well on core component 1 tends to do less well on Task 4 (task component 2). A person who has low scores on core component 1 would tend to perform better on Task 4 than on the remaining tasks. In the Type I analysis there are no other coefficients greater than .75 (absolute). Of the total of 24 core components obtained for the Type II analysis, there are only six that have any coefficients greater than .50 (absolute) and, except for core component 1, there are only two other coefficients greater than .75 (absolute)—they are both .76. Core component 1 shows that the person who has high scores on this component does slightly less well on concept components 4, 5, and 7. Concept component 4 is a specific for the concept Cell; concept component 5 includes the concepts Muscle, Conductor, and Expansion; and concept component 7 is a doublet for the concepts Pore and Volcano. A person with low scores on core component 1 would score slightly better on these concepts than on the remaining ones. Other minor variations in response patterns for the idealized persons can be seen in Table 16.

The three-mode results for the girls are essentially the same as for the boys; there is just one major core component indicating just one idealized person type. As with the boys, the Type I analysis indicates that girls respond similarly to the concepts of the three different areas; they do less well on Task 4 (task component 2) than on the remaining tasks. Of the total of 21 idealized person components from the Type II analysis, only four have any coefficients greater than .50 (absolute) and only one has any coefficients greater than .75 (absolute). This analysis indicates that girls with high scores on this component tend to do less well on concept components 4 and 5 for all of the tasks and on concept components 2 and 6 for Tasks 3 and 4. Concept component 2 includes the concepts Cell, Moon, and Conductor; concept component 4 is a doublet for the concepts Bird and Fossil; Lens and Sedimentary Rock are the concepts appearing on concept component 5; and concept component 6 is a doublet for Invertebrate and Conductor. There are no other coefficients greater than .75 for either of the analyses for girls. Minor variations in response patterns for the idealized persons can be seen in Table 17.

The results for the three-mode factor analyses support the hypothesis that there are no important concept-task interactions for the idealized persons. Thus, it is reasonable to regard these two modes as independent.

Table 16
Three-Mode Core Results: Boys

Idealized Persons	Task Components[a]	Type I Concept Components: Area 1	Area 2	Area 3
1	1	1.79	1.74	1.79
	2	.75	.63	.73
	3	1.95	2.00	1.87
2	1	.43	.61	.20
	2	.12	.28	.29
	3	-.43	-.39	-.56

Type II

Idealized Persons	Task Components[a]	Concept Components: 1	2	3	4	5	6	7	8
1	1	1.29	1.20	1.37	.81	.85	1.21	.72	1.10
	2	1.17	1.14	1.05	.77	.60	1.12	.55	.87
	3	1.70	1.70	1.62	.96	1.03	1.73	.97	1.44
2	1	.28	-.09	.18	.17	-.30	.65	.03	.08
	2	.71	.35	.07	-.16	.00	.76	.20	.09
	3	-.25	-.39	-.37	-.25	-.38	-.35	-.14	-.29
3	1	-.20	-.23	-.14	.62	-.27	.05	-.56	.02
	2	-.04	-.20	.45	-.45	.13	.28	-.32	.07
	3	-.01	.07	.31	-.05	.18	-.06	-.13	.13
4	1	-.23	.76	.29	.06	-.04	.02	-.04	-.15
	2	-.11	-.23	.09	.26	.24	.26	-.12	-.49
	3	-.09	.01	-.16	.05	.01	-.04	.12	-.31
5	1	.06	-.04	-.07	.24	.17	.09	.16	-.36
	2	-.08	.21	-.54	-.25	.12	.27	-.45	-.49
	3	.11	.12	-.03	-.10	.05	.22	.04	.06
6	1	-.41	-.13	-.04	-.01	.28	.27	.28	.05
	2	-.11	.05	.01	-.10	.51	-.15	-.08	.04
	3	-.12	-.03	.06	.01	.20	-.14	-.08	.04

[a]Variables comprising task components:

Type I: 1 - Tasks 1, 2, 3, and 5
2 - Task 4
3 - Tasks 6-12

Type II: 1 - Tasks 1, 2, and 4
2 - Tasks 3 and 5
3 - Tasks 6-12

Table 17
Three-Mode Core Results: Girls

Type I

Idealized Persons	Task Components[a]	Concept Components Area 1	Area 2	Area 3
1	1	1.00	1.00	1.03
	2	.73	.58	.81
	3	2.31	2.34	2.21
2	1	-.43	-.18	-.28
	2	-.40	-.62	-.38
	3	.13	.18	.52

Type II

Idealized Persons	Task Components[a]	Concept Components 1	2	3	4	5	6	7
1	1	2.17	.81	1.32	.27	.35	.84	1.08
	2	1.46	.60	.87	.21	.16	.31	.83
	3	2.32	1.17	1.87	.63	.43	1.06	1.61
2	1	.51	-.15	.27	.56	-.21	-.17	.22
	2	.47	.02	.51	-.19	-.25	-.34	.59
	3	-.56	-.45	-.15	-.14	-.27	-.37	-.19
3	1	.10	.61	-.20	-.04	.07	-.01	.30
	2	-.02	-.52	-.37	.22	.30	-.25	.44
	3	-.13	-.01	-.03	.01	.17	-.06	-.01
4	1	-.15	-.08	-.08	.10	.19	.11	.12
	2	-.06	.54	.10	.07	.45	-.31	.17
	3	-.11	.01	-.05	-.11	.07	.14	.01

[a]Variables comprising task components:

Type I: 1 - Tasks 3 and 5
2 - Task 4
3 - Tasks 6-12

Type II: 1 - Tasks 1, 2, and 5
2 - Tasks 3 and 4
3 - Tasks 6-12

IV
Summary and Conclusions

The primary objective of the project entitled "A Structure of Concept Attainment Abilities" is to formulate one or more models or structures of concept attainment abilities, and to assess their consistency with actual data. This paper contains a report of the factor analytic study of the content and task dimensions of the science items.

Science items to measure concept attainment were developed using a completely crossed design utilizing 30 concepts and 12 tasks. These science items were administered during the fall of 1970 to 186 boys and 259 girls who were just beginning the sixth grade.

Two types of total scores were secured from the students' responses to these items—a total score for each of the 30 concepts (totalled across tasks) and a total score for each of the 12 tasks (totalled across concepts). Means, standard deviations, and Hoyt reliability estimates were obtained for each of the 30 concept scores and each of the 12 task scores for each of the groups studied.

Conventional factor analyses were performed on the intercorrelation matrices obtained for the concepts and for the tasks separately for the boys and the girls. Analyses were obtained using three initial factor methods: Alpha (Kaiser & Caffrey, 1965), Harris $R-S^2$ (Harris, 1962), and Unrestricted Maximum Likelihood Factor Analysis (Jöreskog, 1967). Derived orthogonal solutions were obtained for each of the three initial solutions using the Kaiser normal varimax procedure (Kaiser, 1958), and derived oblique solutions were obtained using the Harris-Kaiser independent cluster solution (Harris & Kaiser, 1964).

Three-mode factor analysis (Tucker, 1966a, 1966b) was performed on two different forms of the same data to determine whether there are any important concept-task interactions for the idealized persons.

The conventional factor results for the concepts yielded one or more orthogonal factors for the various methods. The concept variables are almost all of complexity 2, 3, and even greater on these factors, however. The oblique results tend to yield simple structure but the oblique factors are very highly correlated; thus, a main conclusion is that all 30 of the concepts are measures of a single functional relationship existing among the concepts. This holds for both boys and girls.

As with the concepts, the most reasonable interpretation for the tasks is that all 12 of the tasks are measures of a single underlying ability or latent trait. The intercorrelations of the oblique factors are extremely high when more than one factor is yielded.

The results for the three-mode factor analyses support the hypothesis that there are no important concept-task interactions for the idealized persons. Thus, it is reasonable to regard these two modes as being independent.

A further interesting aspect of studying these science items will be to see how they are related to concepts from three other subject matter fields (mathematics, language arts, and social studies) and to general cognitive abilities. The data for such a study will be collected during summer, 1971. Even though the most reasonable interpretation is that there is only a single common factor for the 30 concepts, the most specific results obtained were used to determine the science concepts to be included in the summer, 1971, study. This should permit maximal demonstration of relationships with concepts from other subject matter fields. The two concepts with the highest coefficients on each of the Harris $R-S^2$ factors for both the boys and girls were selected.

On this basis a total of 21 science concepts were selected for further study. These concepts are: Bird, Cell, Heart, Invertebrate, Lens, Lungs, Muscle, Core, Fossil, Glacier, Meteor, Sedimentary Rock, Volcano, Conductor, Expansion, Friction, Liquid, Melting, Molecule, Sound, and Thermometer. Even though the most reasonable interpretation for the tasks is that there is a single common factor, all 12 of the tasks will be included in the summer, 1971, study in order to have a reliable concept score (totalled across the 12 tasks for a single concept).

References

Bourne, L. E., Jr. Human conceptual behavior. Boston: Allyn & Bacon, 1966.

Frayer, D. A., Fredrick, W. C., & Klausmeier, H. J. A schema for testing the level of concept mastery. Wisconsin Research and Development Center for Cognitive Learning, Working Paper No. 16, 1969.

Harris, C. W. Some Rao-Guttman relationships. Psychometrika, 1962, 27, 247-263.

Harris, C. W., & Kaiser, H. F. Oblique factor analytic solutions by orthogonal transformations. Psychometrika, 1964, 29, 347-362.

Harris, M. L., & Harris, C. W. A factor analytic interpretation strategy. Wisconsin Research and Development Center for Cognitive Learning, Technical Report No. 115, 1970. Also published in Educational and Psychological Measurement, 1971, 31, 589-606.

Harris, M. L., Harris, C. W., Frayer, D. A., & Quilling, M. R. A structure of concept attainment abilities: The problem and strategies for attacking it. Wisconsin Research and Development Center for Cognitive Learning, Theoretical Paper No. 32, in press.

Jöreskog, K. G. Some contributions to maximum likelihood factor analysis. Psychometrika, 1967, 32, 443-482.

Kaiser, H. F. The varimax criterion for analytic rotation in factor analysis. Psychometrika, 1958, 23, 187-200.

Kaiser, H. F. A second generation Little Jiffy. Psychometrika, 1970, 35, 401-415.

Kaiser, H. F., & Caffrey, J. Alpha factor analysis. Psychometrika, 1965, 30, 1-14.

Klausmeier, H. J., Harris, C. W., Davis, J. K., Schwenn, E., & Frayer, D. A. Strategies and cognitive processes in concept learning. The University of Wisconsin, Cooperative Research Project No. 2850, 1968.

Tucker, L. R. Experiments in multimode factor analysis. In A. Anastasi (Ed.), Testing problems in perspective. Washington, D.C.: American Council on Education, 1966a.

Tucker, L. R. Some mathematical notes on three-mode factor analysis. Psychometrika, 1966b, 31, 279-311.

Tucker, L. R, & Lewis, C. A reliability coefficient for maximum likelihood factor analysis. University of Illinois at Urbana-Champaign, Department of Psychology Research Report, 1970.

Voelker, A. M., & Harris, M. L. Measuring science concept attainment of elementary school boys and girls. Wisconsin Research and Development Center for Cognitive Learning, Technical Report No. 197, in press.

Voelker, A. M., & Sorenson, J. S. Items for measuring the level of attainment of selected classificatory science concepts by intermediate grade children. Wisconsin Research and Development Center for Cognitive Learning, Working Paper No. 58, 1971.

Voelker, A. M., Sorenson, J. S., & Frayer, D. A. An analysis of selected classificatory science concepts in preparation for writing tests of concept attainment. Wisconsin Research and Development Center for Cognitive Learning, Working Paper No. 57, 1971.

GPO 827-870-3

Appendix A
Orthogonal Common Factor Results for Science Concepts: Boys[a]

Concept	Alpha A-1	Harris R-S^2 H-1	H-2	H-3	H-4	H-5	H-6	H-7	H-8	UMLFA U-1	U-2
Area: Biological Science											
1 Bird	77	57	36							60	48
2 Cell	74		58							40	65
3 Fish	82	61					31	31		79	37
4 Heart	84	46	31	32	32					63	56
5 Invertebrate	73	38					52			58	46
6 Lens	77		39	33				45		47	61
7 Lungs	86	60		36						73	48
8 Mammal	77	58					33			68	41
9 Muscle	82	34		40		36				54	60
10 Pore	83	50	37	31		34				60	58
Area: Earth Science											
11 Cloud	86	49	38	35						59	62
12 Core	80	41				53				62	52
13 Fossil	83	59			42					72	45
14 Glacier	81	66	32							69	45
15 Meteor	80	33	37		51					50	63
16 Moon	81	41	39	35						50	64
17 Planet	83	46	37							58	59
18 Sedimentary Rock	75	43	43							54	52
19 Volcano	84	56		33				35		67	51
20 Wind	84	59	36			31				69	50
Area: Physical Science											
21 Conductor	71		63							36	65
22 Evaporation	83	34	39	43	31					47	70
23 Expansion	82	41	47	38					31	47	69
24 Friction	76		42				39			48	59
25 Liquid	77	39	32						37	52	57
26 Melting	81	43		43	32					56	59
27 Molecule	74		39	55						36	69
28 Solid	83	58	40							61	56
29 Sound	81	40	34		46					56	58
30 Thermometer	81	49				31		33		64	51

[a]Includes those variables which have coefficients greater than .30 (absolute).

Decimals have been omitted.

Appendix B
Orthogonal Common Factor Results for Science Concepts: Girls[a]

	Alpha	Harris R-S2							UMLFA		
Concept	A-1	H-1	H-2	H-3	H-4	H-5	H-6	H-7	U-1	U-2	U-3
Area: Biological Science											
1 Bird	68		60						32	34	56
2 Cell	65			62						57	
3 Fish	78	44	50						57		52
4 Heart	78	35	35	33				45	57	36	42
5 Invertebrate	67		31	31		36			41	41	33
6 Lens	64	55							51	34	
7 Lungs	84	50				35		35	71	41	
8 Mammal	76	44	52						48	33	53
9 Muscle	72	32		45		32			45	53	
10 Pore	80	42	34		42	38			58	45	34
Area: Earth Science											
11 Cloud	80	35	39	34		32			45	51	41
12 Core	74	48							56	38	34
13 Fossil	80		55	32					36	44	61
14 Glacier	76	41	37			34			54	39	39
15 Meteor	78		37	52					34	61	40
16 Moon	80	31		50	35				41	68	
17 Planet	81	39		32	42				50	56	32
18 Sedimentary Rock	69	54							57	36	
19 Volcano	76	38	34	35					47	46	37
20 Wind	78	48	38					31	64	32	40
Area: Physical Science											
21 Conductor	66			41						58	
22 Evaporation	81	32	32	41	39	34			44	61	33
23 Expansion	79		33		50				44	55	38
24 Friction	73			35	56				34	58	34
25 Liquid	80	41	36	32	38				50	49	38
26 Melting	78	36		33			40		46	50	38
27 Molecule	65					52			41	42	
28 Solid	79	32	34		32	34	33		48	46	43
29 Sound	80		54	32			31		34	44	65
30 Thermometer	70	37			32		34		45	39	38

[a]Includes those variables which have coefficients greater than .30 (absolute).

Decimals have been omitted.

33/34

Appendix C
Orthogonal Common Factor Results for Science Tasks: Boys[a]

Task	Alpha	Harris R-S[2]		UMLFA		
	A-1	H-1	H-2	U-1	U-2	U-3
1 Given name of attribute, select example.	89	53	72	60	48	56
2 Given example of attribute, select name.	92	57	72	63	55	42
3 Given name of concept, select example.	83	40	80	71	41	31
4 Given name of concept, select nonexample.	79	47	66	55	48	
5 Given example of concept, select name.	90	50	79	88	46	
6 Given concept, select relevant attribute.	91	80	47	41	80	
7 Given concept, select irrelevant attribute.	87	76	44	38	75	
8 Given definition of concept, select name.	93	74	58	52	73	
9 Given name of concept, select definition.	92	80	49	46	81	
10 Given concept, select supraordinate concept.	93	69	61	55	68	
11 Given concept, select subordinate concept.	91	73	54	51	71	
12 Given two concepts, select relationship.	86	79	42	36	79	

[a]Includes those variables which have coefficients greater than .30 (absolute).

Decimals have been omitted.

Appendix D
Orthogonal Common Factor Results for Science Tasks: Girls[a]

Task	Alpha	Harris R-S[2]		UMLFA		
	A-1	H-1	H-2	U-1	U-2	U-3
1 Given name of attribute, select example.	88	61	57	59	49	46
2 Given example of attribute, select name.	89	55	67	53	60	45
3 Given name of concept, select example.	86	48	74	47	70	
4 Given name of concept, select nonexample.	77	37	76	36	79	
5 Given example of concept, select name.	86	48	73	48	69	31
6 Given concept, select relevant attribute.	89	77	44	76	39	
7 Given concept, select irrelevant attribute.	83	76	38	75	34	
8 Given definition of concept, select name.	91	72	51	73	45	35
9 Given name of concept, select definition.	93	76	53	77	48	
10 Given concept, select supraordinate concept.	92	73	55	73	51	
11 Given concept, select subordinate concept.	88	72	51	73	48	
12 Given two concepts, select relationship.	86	76	45	76	42	

[a]Includes those variables which have coefficients greater than .30 (absolute).

Decimals have been omitted.

GPO 827-670-2

National Evaluation Committee

Helen Bain
Immediate Past President
National Education Association

Lyle E. Bourne, Jr.
Institute for the Study of Intellectual Behavior
Universiy of Colorado

Jeanne S. Chall
Graduate School of Education
Harvard University

Francis S. Chase
Department of Education
University of Chicago

George E. Dickson
College of Education
University of Toledo

Hugh J. Scott
Superintendent of Public Schools
District of Columbia

H. Craig Sipe
Department of Instruction
State University of New York

G. Wesley Sowards
Dean of Education
Florida International University

Benton J. Underwood
Department of Psychology
Northwestern University

Robert J. Wisner
Mathematics Department
New Mexico State University

Executive Committee

William R. Bush
Director of Program Planning and Management
and Deputy Director, R & D Center

Herbert J. Klausmeier, Committee Chairman
Director, R & D Center

Wayne Otto
Principal Investigator
R & D Center

Robert G. Petzold
Professor of Music
University of Wisconsin

Richard A. Rossmiller
Professor of Educational Administration
University of Wisconsin

James E. Walter
Coordinator of Program Planning
R & D Center

Russell S. Way, ex officio
Program Administrator, Title III ESEA
Wisconsin Department of Public Instruction

Faculty of Principal Investigators

Vernon L. Allen
Professor of Psychology

Frank H. Farley
Associate Professor
Educational Psychology

Marvin J. Fruth
Associate Professor
Educational Administration

John G. Harvey
Associate Professor
Mathematics

Frank H. Hooper
Associate Professor
Child Development

Herbert J. Klausmeier
Center Director
V. A. C. Henmon Professor
Educational Psychology

Stephen J. Knezevich
Professor
Educational Administration

Joel R. Levin
Associate Professor
Educational Psychology

L. Joseph Lins
Professor
Institutional Studies

Wayne Otto
Professor
Curriculum and Instruction

Thomas A. Romberg
Associate Professor
Curriculum and Instruction

Peter A. Schreiber
Assistant Professor
English

Richard L. Venezky
Associate Professor
Computer Science

Alan M. Voelker
Assistant Professor
Curriculum and Instruction

Larry M. Wilder
Assistant Professor
Communication Arts