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ABSTRACT

This issue of INVESTIGATIONS IN SCIENCE EDUCATION (ISE) provides analytical abstracts, prepared by science educators, of research reports in the areas of individual analysis, instruction, cognitive development, and Piagetian studies. Each abstract includes bibliographical data, research design and procedure, purpose, research rationale, and an abstractor's analysis of the research. Some abstracts are clustered by topics investigated. (SL)

Vol. 2, No. 2 1976

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INVESTIGATIONS IN SCIENCE EDUCATION

Expanded Abstracts and Critical Analyses of Recent Research

National Association for Research in Science Teaching

ERIC Science, Mathematics, and Environmental Education Information Analysis Center

The Center for Science and Mathematics Education
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from the Editor

This issue continues the practice of presenting analyses of research reports in clusters based upon a common focus. The first group, INDIVIDUAL ANALYSES, contains critiques of reports on an individual basis. The second group, INSTRUCTION, contains two studies dealing with the relationship of instruction to student outcomes. Three studies related to developmental factors are grouped together under COGNITIVE DEVELOPMENT. Finally, the section entitled PIAGETIAN STUDIES includes a slightly different approach to the clustering of studies. This section contains five related studies based upon Piagetian theory, conducted by basically the same team of researchers, and all analyzed by the same reviewers.

As in past issues, your publishable responses are invited as are suggestions for improving INVESTIGATIONS IN SCIENCE EDUCATION.

Stanley L. Helgeson
Editor

Patricia E. Blosser
Associate Editor

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INDIVIDUAL ANALYSES

EJ 053 662

Lehman, Robert A., "The Effects of Creativity and Intelligence on Pupils' Questions in Science." Science Education, Vol. 56, No. 1:103-121, 1972.

Descriptors--*Creativity, Grade 9, *Intelligence, *Questioning Techniques, *Student Characteristics, Secondary School Science

Expanded Abstract and Analysis Prepared Especially for I.S.E. by N. Eldred Bingham, University of Florida.

Purpose

The purpose of this investigation was to determine which students were asking what kinds of questions. Specifically, how do variations in intelligence and creativity affect the number and level of questions being asked by junior high school science students? The five major objectives were to determine:

1. How variations in intelligence and creativity relate to the total questions and/or the number of questions at each level on the taxonomical hierarchy.
2. If the levels and/or the total number of questions asked can be used to predict creativity.
3. How the levels and/or the total number of questions asked are related to intelligence.
4. If high, medium, and low intelligence groups and high, medium, and low creative groups can be differentiated by the level of questions asked.
5. If the groups associated with each science teacher can be differentiated by the levels of questions they ask.

The six hypotheses tested were:

Hypothesis I - There are no significant differences in the questions asked (concrete, abstract, and creative) due to differences in intelligence or creativity.

Hypothesis II - The levels and total number of questions asked cannot be used to predict creativity.

Hypothesis III - The levels and total number of questions asked are not related to intelligence.

Hypothesis IV - High, medium and low intelligence groups cannot be differentiated by the levels of questions asked.

Hypothesis V - High, medium, and low creative groups cannot be differentiated by the levels of questions asked.

Hypothesis VI - The groups associated with each science teacher cannot be differentiated by the levels of questions asked.

Rationale

One of the most important and pervasive goals of educators at all levels is to develop skills and processes to improve both divergent and convergent production.

Many have indicated that teachers can guide the thought processes of students by carefully choosing the questions they use in the classroom. Educators agree that the questions asked of students should stimulate thinking, but they also confirm that not all students are stimulated by the same questions. It follows that questioning strategies should be developed that will aid individual students. By improving "question-asking" behavior of both students and teachers, it might be possible to aid individual students in developing their natural abilities and thinking processes.

Before developing thinking ability and questioning behavior, it is necessary to determine what skills and processes students are now capable of using.

Research Design and Procedure

A sample of 164 junior high school science students from two schools were administered an intelligence test, a creativity test, and a question generating experiment. High, medium, and low groups were formed for both intelligence and creativity. Three trained judges classified the students' questions into three categories or levels: concrete, abstract, and creative. The hypotheses were tested by use of multivariate analysis of variance, multiple regression, discriminant analysis, and multivariate analysis of covariance.

Findings

1. There is a difference in the total number of questions asked by high, medium, and low intelligence groups. The higher intelligence students asked the most questions while the lower IQ students asked the least.

2. There is a difference in the total number of questions asked by high, medium, and low creative groups. The higher creative students asked the most questions and the less creative students asked the least questions.

3. There is a difference in the number of questions asked at each level by the high, medium, and low intelligence groups. The high intelligence groups asked more questions at all levels; particularly at the concrete level.

4. There is a difference in the number of questions asked at each level between the high, medium and low creative groups. The high creative group asked more questions at all levels, particularly at the abstract and creative level.

5. The abstract and creative levels of questions and total number of questions can be used to predict creativity when the effects of intelligence are controlled. The concrete questions do not account for a significant amount of the variance in predicting creativity. Total questions also account for a significant amount of the variance in the prediction of creativity.

6. When the effects of creativity are partialed out, neither concrete, abstract or creative questions account for a significant amount of the variance in predicting intelligence.

7. Creative questions account for most of the difference between the three levels of intelligence.

8. High, medium and low creative groups can be differentiated by the levels of questions asked. When the variables of concrete, abstract and creative questions are considered simultaneously, they do significantly discriminate between the creativity groups. The univariate F-tests show that these groups are being separated by abstract and creative questions.

9. Using intelligence and creativity as covariates, the groups of students associated with each science teacher can be differentiated when the three categories of questions (concrete, abstract and creative) are considered simultaneously. The univariate F-tests showed that the only level at which there was a significant difference was that of creative questions.

Interpretations

It has been shown in this study that intelligence and creativity do affect the level of questions that students ask in science. The effects that IQ and creativity had tended to be somewhat different. Intelligence seemed to be more related to the convergent type of questions as represented in this study by the concrete category and creativity was related more to the divergent type of thinking. The divergent levels were represented by the abstract and creative categories used in this research. It also appeared that the total number of questions asked was more affected by creativity than by intelligence. Before generalizing too far beyond this sample and the procedures followed, this study should be replicated.

The results of this study also indicated that asking questions of groups may not be the best teaching method. If the kinds of questions students ask are representative of the type of thinking they themselves are doing, then not all students are operating at the higher levels. Perhaps many students' questioning abilities can be improved by following the suggestions offered by Strasser (1) and Torrance (2). They have indicated that being respectful of unusual questions and keeping records of student responses will help to improve questioning behavior. The effect of teachers on creative question-asking, when the influences of creativity and intelligence are controlled, certainly indicates that "question-asking" training should be included in teacher training programs.

ABSTRACTOR'S ANALYSIS

Even though much of what goes on in many classrooms is presenting something, all true teaching is interaction between teacher and students. The use of questions by students or by teachers is perhaps the most effective way of initiating and extending interaction or probing the concepts, interests, and difficulties that may be present. One needs to know as much as possible about appropriate kinds of questions to ask in particular situations. It should prove helpful in teaching to know as much as possible about the effects of creativity and intelligence on questions. The study is relevant to what happens in the classroom. Regrettably, relatively few studies have been concerned with this particular qroblem.

The use of a multivariate approach to the treatment of the data made possible the identification of a number of different qualities of questions that relate to creativity, and the assessment of these factors as they relate to different levels of intelligence. I'm unaware of other studies in this particular area that have used this multivariate approach. Even though this study was done with students in but two junior high schools, the nature of the study and the size of the sample make the results valid and generalizable to other situations.

The written report is adequate but it includes many more tables than are necessary and it is difficult to read. To quickly grasp what the author has been doing, one needs to turn to the summary first, and then read the report from the beginning. It would ease the track of the reader if the author had followed the outline of topics presented in these abstracts in his presentation. As he presented the information, one doesn't discover the particular hypotheses that are being tested until he reads the "results of hypothesis testing."

This study, having identified the effects of creativity and intelligence on many types of pupils questions can serve as a base for many specific researchers on these factors that truly promote creativity.

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EJ 107 961

Durkee, Phillip, "An Analysis of the Appropriateness and Utilization of TOUS with Special Reference to High-Ability Students Studying Physics." Science Education, Vol. 58, No. 3:343-356, 1974.

Descriptors--*Achievement, Critical Thinking, Educational Research, *Physics, Science Education, *Secondary School Science, *Scientific Enterprise, Scientific Literacy, Science Teachers

Expanded Abstract and Analysis Prepared Especially for I.S.E. by Victor E. Lopez-Tosado and Fletcher G. Watson, Harvard University.

Purpose

This study was done to: (1) investigate the change in "understanding the nature of science" among talented secondary students studying a physics-astronomy course during a summer institute; (2) compare the level of understanding of this high-ability student group with other student and teacher groups; and (3) investigate the correlation between "understanding the nature of science" and "critical thinking" and "science achievement."

Rationale

Great emphasis has been given to the importance of learning in this area--the understanding of the nature of science--hence the importance of measuring it. Knowledge of how students do in this area might help in the developing of better teaching materials and teaching methods.

Research Design and Procedure

The sample consisted of 29 juniors and seniors attending the 1972 six week Secondary Science Training Program (SSTP) at the University of Iowa, Iowa City. For data gathering on the variables under study the Test on Understanding Science (TOUS), the Watson-Glaser Critical Thinking Appraisal (WGCTA), and the PSSC Test of General Course Objectives were used. Students were pre- and post-tested on all three instruments.

Variables used in the assessments were: (1) "understanding the nature of science," (2) physics achievement, and (3) critical thinking ability. Data on these variables were collected during the SSTP and compared with data reported by other authors for groups of physics students, high ability students, and physics teachers. Zero-order correlations, multivariate correlations, and regression analysis of variance were used to study the relationship between the criterion ("understanding the nature of science") and independent ("Critical thinking ability") and ("Science achievement") variates.

Findings

Results of the pre- and post-test comparison for the physics-astronomy students of the Iowa SSTP gave a nonsignificant difference (level of significance of .05) in their understanding of the nature of science as compared by TOUS. A positive change was observed, however.

Comparing results of the SSTP high-ability group with TOUS means of physics students in general, a difference ranging between 3 and 7 points was observed. The Iowa SSTP high-ability group obtained a mean of 43.2. The national norms (tentative) of 11th and 12th grades as established by Cooley and Klopfer (1) have means about 11 points below the Iowa group. Similar means scores were obtained by the SSTP high-ability groups and other high-ability or high-IQ groups.

Findings of Rothman (2) and Welch and Walberg (3) indicate a wide range of mean scores for groups of secondary school physics teachers: a range of 41-50. The Iowa SSTP group score higher in two out of five reported studies.

"Critical thinking ability" and "science achievement" appear to be moderately correlated (range of .47-.62) with "understanding the nature of science," both for the high ability STTP group and other student groups. In the test for linearity, a non-significant departure from linearity (.2 level of significance) was established. However, no significant increase in the power to predict "understanding the nature of science" was achieved by adding "critical thinking ability" as a second independent variable to "science achievement" in the regression equation.

The author's general conclusion of the study is ". . . that 'understanding the nature of science' is cognitively speaking, largely independent of 'critical thinking ability' and 'achievement in science': that many physics teachers have less understanding of the nature of science than high-ability secondary students, and that TOUS scale I may not be capable of functioning to discriminate the level of ability of a substantial portion of high ability students . . .".

Interpretations

Durkee concludes, after analyzing the non-significant TOUS gains for the Iowa group, "that in order to achieve significant growth in TOUS scores, the specific concepts and knowledge of the nature of science . . . have to be taught, rather than expecting this knowledge to be assimilated via a kind of osmotic processes during the regular science activities.

Another inference about the non-significant gain observed is that the instrument utilized (TOUS) may not be entirely appropriate, especially Scale I. Eight students (30 percent of the sample) missed no more than two items on this scale on the pre-test, suggesting that a "ceiling effect" may have occurred.

The small to medium correlation coefficients between the WGCTA and TOUS suggest that probably other factors have "a great deal more than critical thinking and science achievement" to do with understanding the nature of science.

ABSTRACTOR'S ANALYSIS

The purpose of the study is of great importance and should provide valuable information for those engaged in science teaching and/or developing science teaching materials. But the conclusions obtained, although they cannot be overlooked, have to be considered with caution. The main concern with the study is the way the sample of students was selected. Nine students were from Iowa and the rest (20) from other states. No additional information, besides being high-ability students, about them or how they were selected, was given. This poses a great doubt on whether the generalizations made can be extrapolated to the general population of high-ability students. If this is the case, in my opinion, the author's findings need to be confirmed by other investigators.

Another concern which needs to be considered is the lack of information given by the author in regard to the validity and reliability measures of the different instruments utilized. Only on TOUS was this information readily available.

Some of the data from other authors for making the comparisons were incomplete, i.e., they did not report standard deviations, information in regard to sample collections, etc. Due to these missing data, the author in making his analysis, rested on assumptions about the data that do not necessarily hold. This was unfortunate.

It is important to note that the author was conscious of these limitations and pointed them out wherever they existed.

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EJ 103 099

Thorsland, Martin N. and Joseph D. Novak, "The Identification and Significance of Intuitive and Analytic Problem Solving Approaches Among College Physics Students." Science Education, Vol. 58, No. 2:245-265, 1974.

Descriptors--Academic Achievement, College Science, Critical Thinking, Educational Research, *Logical Thinking, Physics, *Problem Solving, *Science Education, *Thought Processes.

Expanded Abstract and Analysis Prepared Especially for I.S.E. by N. Eldred Bingham, University of Florida.

Purpose

The purpose of the study was to identify and assess intuitive and analytic modes of thinking in physics, to associate these modes with Ausubel's theory of learning, and to estimate learning efficiency of students whose approach is high or low I (intuitive), or high or low A (analytic). The hypotheses were concerned with the relationship between the A and I dimension and various related parameters. They were:

Hypothesis I: The A dimension is more highly related to scholastic ability than is the I dimension.

Hypothesis II: (A) Students rated high I will achieve at significantly higher level than those rated low I; (B) students rated high A will achieve at a significantly higher level than those rated low A.

Hypothesis III: (A) Students rated high I will spend less time in learning than those rated low I. (B) Students rated high A will spend less time in learning than those rated low A.

Hypothesis IV: (A) Students rated high I will be more efficient in learning than those rated low I; (B) Students rated high A will be more efficient in learning than those rated low A.

Rationale

A theory of learning proposed by D. P. Ausubel (1968) was utilized. In this subsumption theory a "differentiated cognitive structure" is the prime determiner of success in learning subsequent related subject matter. Ausubel views cognitive structure as a hierarchical set of concepts (subsumers) to which new information can be associated during meaningful learning. When no relevant subsumers are available for "anchorage" or association of new information, rote learning is necessitated until some rudimentary relevant concept is formed. In an earlier study at Cornell University, Ring and Novak (1971) have demonstrated the importance of subsuming concepts in chemistry to subsequent achievement.

The highly I individual, it is conjectured, would possess the superordinate ideas and higher level subsumers necessary to enable him to move across the upper levels of Figure 1 with frequent referrals to (and from) subordinate concepts. The highly A individual, it is conjectured, would be very effective at regenerating the lower level, subordinate ideas and would therefore move primarily from the subordinate to the superordinate concepts as shown in Figure 2. The analytic dimension is thus treated as an aspect for information-processing ability similar to that set forth previously in a model of concept formation (Novak, 1965). This particular aspect of information processing would play a very important role in such mathematically oriented and highly structured subjects as physics.

Research Design and Procedure

Twenty-five subjects were randomly selected from the 70 auto-tutorial (A-T) students. Each of the 25 participated in a problem solving interview session which was taped for subsequent analysis. From the analysis of the interviews, I and A ratings were assigned to each subject. Four groups of subjects were established according to extremes of the I and A ratings. These groups were then compared on various learning-related parameters.

In addition to the I and A ratings, for each of the 25 subjects in the sample, the following data were also obtained:

a) scholastic aptitude test scores, verbal and math (SATV, SATM);

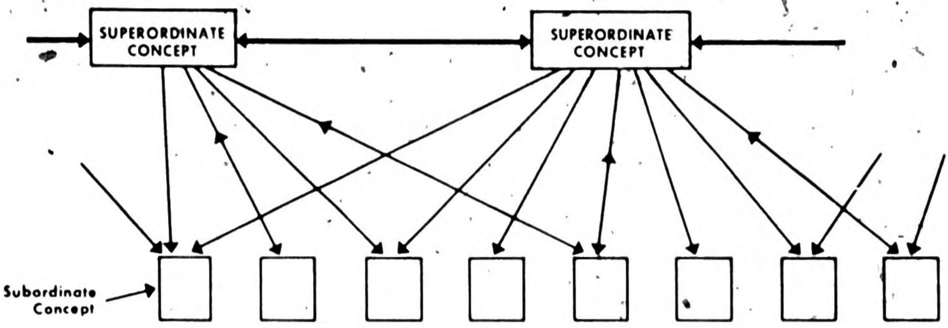
b) achievement on major course exams and weekly quizzes;

c) weekly time spent in learning as recorded in the A-T center; and

d) weekly and total learning efficiency scores (learning efficiency defined as achievement divided by associated learning time; see, later in this paper, a description of learning efficiency).

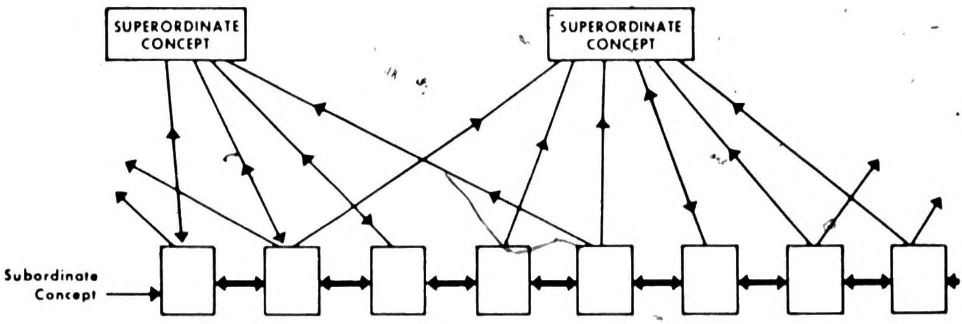
Findings

Hypothesis I: "The analytic dimension is more highly related to scholastic ability than is the intuitive dimension " was supported. The high A, low I student did not differ significantly on either SATV or SATM scores. The student rated as high and low A did differ on both the SATV and SATM scores. These data support the authors'



High Intuitive Individual Moves Freely From One Superordinate Concept to Another with Frequent Referral Primarily TO (and less frequently FROM) Subordinate Examplars.

Figure 1. Representation of the conceptual organization in cognitive structure of the high individual and the relationship to cognitive functioning



High Analytic Individual Moves Primarily Within Subordinate Concepts and To Superordinate Concepts, with Referral Back to Subordinate Concepts, Thus Expanding the Superordinate Concepts. (Very little, if any, exchange between Superordinate Concepts.)

Figure 2. Representation of the conceptual organization in cognitive structure of the high individual and the relationship to cognitive functioning

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position that SAT tests tend to assess lower level concepts and isolated bits of knowledge.

The other hypotheses were also supported:

Hypothesis II: (A) students rated high I will achieve at significantly higher level than those rated low I; (B) students rated high A will achieve at a significantly higher level than those rated low A.

Hypothesis III: (A) students rated high I will spend less time in learning than those rated low I. (B) students rated high A will spend less time in learning than those rated low A.

Hypothesis IV: (A) students rated high I will be more efficient in learning than those rated low I; (B) students rated high A will be more efficient in learning than those rated low A.

For low I, low A students, efficiency of learning was about constant, while for high I, high A students efficiency increased gradually and consistently.

Interpretations

The following general conclusions can be drawn from this study. It is possible to identify consistent and reliable individual differences in problem solving approach and to categorize an individual's preferred mode of attack using as a basis the I and A dimensions. Individuals appear to be reasonably stable in their approach from problem to problem, particularly on the A dimension.

One of the crucial variables relating to the approach an individual uses in problem solving is the degree of differentiation of his cognitive structure and the concomitant availability of subsuming concepts. The individual who possesses the global, superordinate concepts in a discipline (high I) and also has the ability to reconstruct lower level concepts when and if needed (high A) is at a significant advantage in terms of achievement and learning efficiency.

The individual who possesses the ability to regenerate subordinate concepts (high A) but lacks the overall subsuming concept (low I) finds it necessary to spend large amounts of learning time resulting in low efficiency.

There is some evidence to suggest a progressive facilitating effect of A and I ability on new learning. The learning efficiency steadily increased in the high I, high A group. Increases in efficiency for the groups were not as pronounced.

ABSTRACTOR'S ANALYSIS

This is one of a growing number of researches on how children and youth learn. Most of these studies, especially those dealing with the learning of young children, are largely influenced by Piaget's work. These studies have done much to make teachers aware of what they may reasonably expect of children and of the need for a wide range of specific experiences as a base for the development of logical abstract thinking. These studies have also made secondary and college teachers aware that a relatively high percentage of their students are thinking at the concrete level rather than the abstract level and of the necessity to adjust their courses to provide the essential experiences. Furthermore, older students able to think abstractly in a familiar area cannot do so in a field utterly new to them. So-called concrete experiences in the new field are required for them to move to a logical analytical way of thinking.

Recently there has been an increasing number of researches focusing upon the learning theory which D. P. Ausubel proposed in 1968. His theory is concerned with the concepts one brings to a new learning situation, and with the relation of these concepts to new instances available in the new learning situation. He holds that a "differentiated cognitive structure" which permits subsuming new concepts of subsequent related matter into this structure facilitates efficiency in learning; that unless there be this differentiated cognitive structure with higher order concepts available, isolated experiences are quickly forgotten. But if this cognitive structure of higher order concepts is already present in the learner, then the new experience reinforces or enhances the concepts already held. Furthermore, the incidental experiences may be forgotten while the more inclusive abstract concepts are held, yet the learner can reconstruct similar specific experiences if need be. As students move to progressively higher levels in school, this differentiated cognitive structure becomes more necessary in dealing effectively with the complex situations that arise.

By categorizing the subjects in this study as low I, low A; low I, high A; high I, low A; and high I, high A, it was possible to gain new insights into how learning takes place.

Even though the number of subjects was limited to 25, the taped interviews enabled categorizing them as above, and the observer showed a high level of agreement in ranking on both the intuitive and analytic dimensions. The study gave valid results, the research was designed such that the study could be profitably replicated by others, and the report was well written.

There has been but relatively little research in this particular aspect of learning. The replication of this study in other sciences and at other levels could greatly extend present knowledge concerning how learning can proceed most effectively.

I commend this study to any researcher concerned with improving teaching and learning.

INSTRUCTION

EJ 100 017

Trojcak, Doris A., "Training in Programming Instruction and Student Achievement." Journal of Research in Science Teaching, Vol. 11, No. 1:39-44, 1974.

Descriptors--Academic Achievement, Autoinstructional Aids, *Educational Research, *Elementary School Science, Grade 4, *Preservice Education, *Programed Instruction, Programed Materials, *Program Evaluation, Science Education, Teacher Developed Materials

Expanded Abstract and Analysis Prepared Especially for I.S.E. by David R. Stronck, Washington State University.

Purpose

The purpose of this investigation was to determine the influence of five stages of instruction on the prospective teacher's ability to construct programmed science activities for fourth-grade students. The null hypotheses tested (not stated explicitly by the researcher) were the following:

There is no significant difference in scores on a test in which ten objectives for teaching heat conductions to fourth graders were to be sequenced between prospective teachers:

1. who completed one stage of an instructional package and

   (a) those who completed two stages;
   (b) those who completed three stages;
   (c) those who completed four stages;
   (d) those who completed five stages;
   (e) those who completed no stages;

2. who completed two stages of an instructional package and

   (a) those who completed three stages;
   (b) those who completed four stages;
   (c) those who completed five stages;
   (d) those who completed no stages;

3. who completed three stages of an instructional package and

   (a) those who completed four stages;
   (b) those who completed five stages;
   (c) those who completed no stages;

4. who completed four stages of an instructional package and

   (a) those who completed five stages;
   (b) those who completed no stages;

5. who completed five stages of an instructional package and those who completed no stages.

A second major set of hypotheses was the following:

There is no significant difference in scores on a 16 item multiple choice test on friction between fourth-grade students:

1. who were given programmed instruction prepared by the experimental methods students and those who were not given programmed instruction; or

2. who were given programmed instruction prepared by the experimental methods students who spent more than 12 hours developing their programs and those who spent less than 12 hours.

For both hypotheses which consider the scores on the test completed by the fourth graders, there are subhypothesis for each of the five stages of instruction by which the prospective teachers were prepared to construct programmed science activities.

Rationale

One of the most important current educational developments is auto-instructional programming. According to D. J. Klaus (2) in his article "The Art of Auto-Instructional Programming," the commercially available programmed materials will be used responsibly and wisely if the teachers are given training for designing some of the programmed materials which their students will use. In this study, procedures for training prospective teachers to construct and implement auto-instructional materials were developed and evaluated. The five-stage instructional package for the prospective teachers was based especially on R. M. Gagné's article "Instruction and the Conditions of Learning" (1) and S. Thiagarajan's Programmed Programing: Part VI, Developmental Testing (3).

Research Design and Procedure

The research design used throughout this investigation was Post-test-Only Control Group.

The prospective elementary school teachers were divided into two groups: (A) 36 science methods students who received no programmed instruction, and (B) 55 science methods students in the experimental group. This latter experimental group was subdivided into five treatment groups of eleven students in each: (1) whose who received only stage one of the instructional package, (2) those who received stages one and two, (3) those who received stages one, two, and three, (4) those who received the first four stages, and (5) those who received all five stages.

The fourth-grade students were divided into two groups: (A) 118 fourth graders who were not given programmed instruction, and (B) 275 fourth graders in the experimental group. This latter experimental group was subdivided into five treatment groups of 55 students in each: (1) those who were given programmed instruction prepared by the experimental methods students described in treatment group "1" above, (2) those who were given programmed instruction prepared by the methods students in group "2" above, and so on for the five groups.

The participants in all samples were randomly selected. The entire study was done within one semester. Each of the five stages of the instructional package required two or three 50-minute class periods. The time required for constructing programs by the prospective teachers averaged 12 hours but never exceeded 20 hours. The average completion time for the instructional programs done by fourth graders was 40 minutes. The average completion time for the test taken by the fourth graders was 25 minutes.

Duncan's Multiple Range Test was applied to determine the significance of differences among mean scores of the six teacher groups on the sequencing of instruction test and of the six fourth-grade groups on the friction test. A second analysis of data consisted of a 2 x 5 factorial analysis of variance to determine the effects of the amount of time spent in preparing programs on fourth graders' achievement from using the programs.

Findings

Duncan's Multiple Range Test revealed no significant differences among the mean scores of the experimental groups. Nevertheless, all of the experimental groups obtained significantly higher scores than the control groups.

The 2 x 5 factorial analysis demonstrated a significant difference in mean achievement scores obtained by the fourth-grade students associated with the amount of time that the prospective teachers spent in preparing the instructional programs. Those fourth graders who used programs which were prepared with more time obtained higher scores on the achievement test. Moreover, significant differences were found indicating that increasingly higher achievement levels were associated with increasing amounts of training in the five stages of the instructional package. This last finding comes from recording the systematic relation between the proportion of prospective teachers who spent greater amounts of time developing programs and the amount of training they received. The amount of training was directly proportional to the amount of time given to developing programs.

Interpretations

The researcher concluded: "The instruction in programming was instrumental in facilitating the prospective teachers' abilitv to logically sequence objectives and that fourth graders did learn from the programs they used. It was also clear that the full five stages of instruction had a greater effect on developing the prospective teachers' ability to design effective instruction than only one or two stages of instruction. . . . The amount of time spent by the prospective teacher in developing the programs was related to the achievement produced and was found to be a significant factor."

ABSTRACTOR'S ANALYSIS

The investigator has done some very interesting work in the development and evaluation of programmed science activities constructed by prospective elementary school teachers. The recent trend toward individualized instruction has made this an important new topic. Because her study involved the use of new instruments in a new area of investigation, some of the difficulties in obtaining complete data or replicating the data with larger samples are of minor importance with the basic value of this novel research.

Her first problem was the inadequacy of the tests to provide significant differences according to the original hypotheses. One test required the prospective teachers to sequence ten objectives for teaching heat conduction to fourth graders. A second test asked fourth graders to respond to multiple choice questions on friction. Duncan's Multiple Range Test revealed no significant differences among the mean scores of the experimental groups; however, all of the experimental groups obtained significantly higher scores than the control groups. But these control groups provide relatively little information because of these rather obvious assumptions: (1) prospective teachers with some instruction on preparing programmed materials will significantly better sequence ten objectives for teaching a unit than will the prospective teachers without such instruction; (2) fourth-grade students who completed a programmed unit on friction will have significantly higher achievement on a multiple choice test on the topic of fraction than will those without such instruction. If the use of Duncan's Multiple Range Test had not demonstrated significant differences between the control groups and the experimental groups, the data would have shown the work with the prospective teachers to be a serious failure.

The investigator noted: "The analyses suggest that further research should be undertaken to determine if indeed instruction in programming can aid prospective teachers in logically sequencing objectives and that fourth graders did learn from the programs developed." As stated, this suggestion seems unnecessary because the study did reveal the basic success of the instruction in programming as a significant aid in helping prospective teachers to sequence objectives logically. But the tests used did not distinguish between the various stages of the instructional package. The data seem to indicate that only one stage is needed to achieve an adequate ability. The investigator describes stage one: "This segment of instruction focused on a review of performance objectives and their relationship to programmed instruction. The students were given a prototype program . . . [which] exemplified a sequence of prerequisites leading to problem solving ability according to Gagné. . . . Three 50 minute class periods were used to complete stage one." Although the other four stages provided more information on the general topic, the additional hours did not significantly improve the ability of the prospective teachers to sequence objectives or the fourth-grade students to achieve by using the instructional materials provided by those prospective teachers. A conclusion not recognized by the investigator is to reduce the five stage instructional package to only one stage. This reduction would also make the package more attractive for use by other science educators who may wish to consider the same topic in a methods course.

The study also showed that those fourth graders who used programs which were prepared with more time obtained higher scores on the achievement test. This is important information. Some teachers seem to justify careless preparation of instruction by assuming that teaching is an art which is significantly improved only by practical experience. But this study shows that programmed materials are significantly improved simply by dedicating more time to the initial writing. From these data the investigator could arrive at an appropriate definition of the assignment in terms of hours which each prospective teacher should give to constructing the instructional material. This topic was not developed in the article.

The amount of time which the prospective teachers gave to developing programs systematically increased with the amount of training provided in the various stages of instruction. This datum indirectly shows that the attitude of the prospective teachers toward developing programs improves with increased training. The investigator recommended: "New instruments to measure the sequencing and/or programming ability of teachers and professional programmers should be developed." The abstractor recommends that instruments should be developed also to gather data on the opinion of prospective teachers and children toward programmed instruction. The abstractor has used such instruments to measure the attitudes of prospective teachers at Washington State University. He has been discouraged by the general rejection of programmed instruction by prospective elementary school teachers who seem to prefer other modes of instruction. Therefore perhaps the most valuable contribution of the investigator's article is her success at increasing the acceptance of programmed instruction through her five stage package of instruction. Her study did not attempt to identify the attitude of the fourth graders toward programmed instruction in comparison with other modes of instruction.

Although the study has an appropriate research design, the value of the five stage package of instruction will be better analyzed when it is used and evaluated by other instructors of science methods on additional campuses. Hopefully this package will allow a greater introduction of programmed instruction into the elementary schools. Recently commercial companies have published excellent materials for individualized instruction. But the acceptance and appropriate use of these materials remain a major problem in most of our nation's schools and methods courses.

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Shymansky, James A. and Charles C. Matthews, "A Comparative Laboratory Study of the Effects of Two Teaching Patterns on Certain Aspects of the Behavior of Students in Fifth Grade Science." Journal of Research in Science Teaching, Vol. 11, No. 2:157-168, 1974.

Expanded Abstract and Analysis Prepared Especially for I.S.E. by Paul C. Beisenherz, University of New Orleans.

The purpose of this study was to investigate the effects of two sets of learning conditions (teacher-structured and student-structured) on student performance. Eight hypotheses were generated and tested.

1. There is no difference in the L related scores (dependent variable involving the fraction of student behaviors recorded in the lesson-related categories of the SCAS system) between students in the student-structured classroom and the teacher-structured classroom.

2. The interaction effect of learning conditions by student class rank is zero.

3. There is no difference in the LN scores (the fraction of student behaviors recorded in each of the nine L categories--the dependent variable) between students in the student-structured classroom and the teacher-structured classroom.

4. The interaction effect of learning conditions by student class rank is zero.

5. There is no difference in the mean posttest scores on the TAB test (dependent variable) between students in the student-structured classroom and the teacher-structured classroom.

6. The interaction effect of learning conditions by student class rank is zero.

7. There is no relationship between the amount of direct teacher-student interaction (during a "one-to-one" interaction) and the behavior scores of the involved student in the student-structured classroom.

8. There is no relationship between the amount of direct teacher-student interaction and the behavior scores of the involved students in the teacher-structured classroom.

Rationale

The rationale for the study was provided by the paucity of studies that adequately identified a cause and effect relationship between teacher behavior and student performance. To establish more clearly the relationship between various aspects of instructional strategies and student behaviors, the authors identified the need to provide a more systematic and deliberate control of extraneous factors.

Research Design and Procedure

Fifty-two fifth grade students at the Florida State University School were randomly assigned to two classrooms. Both groups were taught science by the same teacher using the same materials and classroom facilities, differing only in the patterns of teacher behavior. Using a listing of teacher behaviors found in Matthews' "SCAS Classroom Interaction Categories--Teacher Behaviors," five categories were identified that characterized the teacher's pattern of behavior in the teacher-structured classroom. Likewise, four categories characterized the student-structured classroom teacher behavior pattern. By determining the fraction (Learning Conditions Index) of the above behaviors in each of the two patterns of behavior to the total number of behaviors recorded using the SCAS categories of teacher behavior, a level of acceptable teacher behavior was established for each pattern. Having established the appropriate levels of teacher behavior in the student-structured and teacher-structured classrooms in the first five weeks of school, observational data on student classroom behavior were then collected by a team of nine observers during the second five weeks of school. The behavior of six students in the student-structured and teacher-structured classroom was coded daily for the duration of the science period.

Hypotheses 1 through 6 were tested using analysis of variance techniques. Hypotheses 7 and 8 were tested using a nonparametric technique, the Spearman rank correlation coefficient rho.

Findings

Abbreviated "source tables" with corresponding F-ratios for Hypotheses 1 through 4 were tested. Significant differences (at the 0.05 level) were reported and are summarized in the next section.

Analysis of the TAB test data revealed a significant difference (0.05 level) in the inquiry skills of the students in the two sets of learning conditions in favor of the student structured students (Hypothesis 5). Hypothesis 6 was not rejected. Estimates of the rho values revealed significant (0.05 level) relationships between the teacher-student interaction scores and the student behavior scores (Hypotheses 7 and 8).

Interpretations

The students exposed to the directive teaching of the teacher-structured classroom performed very differently from the students exposed to the nondirective teaching of the student-structured classroom. The authors state that the data suggest that, "given a classroom in which materials are made available to the student, a teacher who frequently

1. makes statements (including questions), which tell the students what to do or how to do an activity;

2. praises or evaluates students for ideas or behaviors; and

3. rejects and/or discourages student behaviors;

tends to have students who

1. spend more class time observing the teacher;

2. spend more class time following teacher directions regarding what activity to do and/or how the activity should be done;

3. spend less class time doing activities in which no specific teacher directions are followed, i.e., doing an activity of their own design;

4. spend less class time responding to teacher questions;

5. spend more class time initiating (or attempting to initiate) interaction with the teacher and continuing self-initiated interaction with the teacher;

6. spend less class time receiving ideas from another student (who is not demonstrating for the teacher), and

7. spend less class time giving ideas to another student (not at the request of the teacher)."

In addition, the authors state that behavior scores "show clearly that the students in the nondirective learning environment of the student-structured classroom functioned as effectively as, if not more productively than, the students in the teacher-structured classroom. More importantly, the behavior scores reveal that the students conformed to the behavior pattern of the classroom teacher."

The authors interpreted the student observation data and the scores on the TAB test as suggesting that a nondirective, nonevaluating learning atmosphere can be established in an elementary science classroom with no loss of student involvement or constructive activity.

ABSTRACTOR'S ANALYSIS

This study represents a serious attempt to examine an important topic--effects of teacher behavior on student performance. It has been mentioned in earlier "Abstractor's Analysis" that many of the questions concerning research design, procedure, and treatment of data are quite possibly a direct result of the constraints placed upon authors in terms of article length. Many of the following difficulties encountered by the abstractor in interpretating this study are of this nature.

That both groups of students were taught by the same teacher raises questions concerning the teacher's ability to satisfactorily present both patterns of behavior. While the "Learning Conditions Index (LCI)" was a valuable aid in defining acceptable teacher behavior, other more subtle behavior patterns might have been operating during the ten week treatment period. It would appear difficult for many teachers to demonstrate behaviors not typically part of their normal behavior pattern.

The authors stated (page 161) that "observational data on student classroom behavior were then collected by a team of nine observers during the second five weeks of school. The behavior of six students in the student-structured and teacher-structured classroom were coded daily for the duration of the science period..." No estimate of intercoder reliability was reported. Also, information identifying the coders, their training, how they were employed in the classroom, and their effect on the classroom environment would have been helpful. In addition, it was not clear how the sample of six students was selected. Were the same six students coded daily? Were there three or six students selected from each classroom? No mention was made concerning classroom events during the treatment period.

In identifying a profile of teacher behavior in both student-structured and teacher-structured classrooms (Table III), it is not clear how the "percentage of total class time" was determined. How were the incidences of the specified behavior categories converted to class time? If the dominant behavior occurring within each five or ten second period was recorded, then potential sampling problems might exist. Also, the percentage of total class time devoted to the behavior category, "follows teacher directions," for student-structured students was reported (in Table VII) to be 0.0. It is interesting to specualte on the classroom interaction patterns in this particular classroom environment.

Table VI contains "scores representing the total time the teacher interacts nonverbally with a student in a one-to-one situation." How was this time determined? Even if operationally defined, measurement of this class of behaviors would appear to be quite difficult.

Also of importance in this study is the distinction between the two treatment groups--teacher-structured and student-structured. While the individual behavior categories appear satisfactory, the overlapping of categories between the two groups suggests a vaguely defined construct that makes comparisons difficult.

In examining the differences in teacher behavior categories between teacher-structured and student-structured classroom interaction, it appears to the abstractor that the degree of teacher guidance is of some importance to the study. The student-structured pattern implies less guided learning while the teacher-structured pattern suggests more highly guided learning. However, inquiry, as a strategy of instruction, can result from both patterns. If so, it appears difficult to separate inquiry from non-inquiry strategies using the teacher-structured and student-structured categories. Because the TAB test was designed to evaluate a child's ability to demonstrate selected inquiry behaviors under specified conditions, the use of student scores on the TAB test as a dependent variable to test Hypotheses 5 and 6 could be questioned. However its use in this study raises interesting questions for future investigations.

Future research could progress in several directions. For example, studies could be conducted that identify behaviors students demonstrate when taught particular concepts using specific instructional strategies (each strategy operationally defined by a limited number of teacher behaviors).

COGNITIVE DEVELOPMENT

EJ 065 314

Raven, Ronald J., "A Multivariate Analysis of Task Dimensions Related to Science Concept Learning Difficulties in Primary School Children." Journal of Research in Science Teaching, Vol. 9, No. 3:207-212, 1972.

Descriptors--*Concept Teaching, *Cognitive Development, Elementary School Science, *Learning Theories, *Scientific Concepts, *Task Analysis

Expanded Abstract and Analysis Prepared Especially for I.S.E. by Edward L. Smith, Michigan State University.

Purpose

The problem addressed was the need for information concerning the difficulty levels of various conceptual tasks for use in elementary school curriculum development. The purpose was to "determine if achievement in a series of problems was affected by differences among task values within a dimension on which the tasks were described." The following hypotheses were stated:

1. There will be a difference among tasks that have different inference patterns.

2. There will be a difference among tasks that have different goal objects.

3. There will be a difference among tasks that have different percepts.

Rationale

Studies by Bruner (2), Inhelder and Piaget (6), and Elkind (5) are cited as evidence of the importance of "cognitive operations," "content capabilities," and "perceptual abilities" respectively in the solution of concept tasks. The author points out that although substantial work has gone into investigating these abilities, relatively little has been done to identify task dimensions which affect the level of performance on concept tasks. Studies by Osler and Kofsky (8) and by Smedslund (11) had previously found performance to be affected by varying tasks along specified dimensions.

Three dimensions used by Smedlund were adopted for the present study:

1. Inference pattern - "The organizational pattern of the problem which demands specific sets of mental operations for solutions" [Values: compensation (C), transitivity (T), coordination (R)]

2. Goal object - "The end result of what the pupil is instructed to attain" [Values: speed (C), mass (M), momentum (P)]

3. Percept - "What one perceives in the entire problem situation" [Values: weighted balls pushing boxes (a), interacting collision carts (b), moving toy cars (c), balls of clay (d)]

The author views these task dimensions as corresponding to the three types of learner abilities listed above, and therefore likely to be useful in characterizing the difficulty levels of concept tasks.

Although not stated, the study seems based on the following underlying assumptions:

1. Concept tasks such as those employed in research on concept attainment and cognitive development should be included in curricula.

2. The level of difficulty of such tasks prior to instruction on them should have a direct relationship with their placement within the curriculum.

Research procedure and Design

Sample: Twenty boys and twenty girls were randomly selected from each of the kindergarten, first, second, and third grades of an elementary school characterized as having a largely middle class population.

Tasks: Eight tasks were used in the study (see Table 1). These tasks represent 8 of the 36 types of tasks generated by combining all values of the 3 task dimensions (3 inference patterns x 3 goal objects x 4 percepts). The author does not indicate how these eight tasks were selected.

Procedure: The eight tasks were administered in random orders to individual children. Each task was administered twice to each child. A positive score required correct answers to the criterion question in both instances. The magnitude of the positive scores was not reported. Zero was assigned when one or both questions were missed. Brief descriptions of each task were presented by the author.

Design: Each of the three task dimensions was used as an independent variable. Each child was given all eight tasks making this a repeated measures (within subjects) design for these independent variables. In addition, grade and sex represent potential between subject (blocking) variables. The dependent variables were the task scores combined according to the values of the task dimensions to which they correspond. The author does not report how the task scores were combined (e.g., mean, sum, etc.).

In terms of the Campbell and Stanley (3) notation, this design comes closest to the Counterbalanced Design (No. 11). However, the author does not indicate that the design was strictly counterbalanced

TABLE 1
DIMENSIONAL VALUES DESCRIBING THE TASKS USED IN THE STUDY*

Task Code	Task	Dimension: Inference Pattern	Dimension: Goal Object	Dimension: Percept
CSa	S must adjust (and justify) the speed of unequally weighted balls to cause similar boxes to move equal distances when struck.	compensation	speed	weighted balls pushing boxes
CMa	S must adjust (and justify) the mass of unequally weighted balls to cause similar boxes to move equal distances when struck.	compensation	mass	weighted balls pushing boxes
CPb	S must indicate (and justify) the relative number of bricks on two unequally weighted collision carts which have traveled equal distances after interacting.	compensation	momentum	interacting collision carts
TSc	After observing 3 toy cars moving at differing speeds and then establishing that a went faster than b and that b went faster than c; S must indicate (and justify) that a went faster than c.	transitivity	speed	moving toy cars
TMd	After observing 3 balls of clay of differing mass and then establishing that a has more clay than b, and that b has more than c, S must indicate (and justify) that a has more than c.	transitivity	mass	balls of clay
TPb	After observing two pairs of collision carts interacting and establishing that a has more bricks than b and that b has more bricks than c, S must indicate (and justify) that a has more bricks than c.**	transitivity	momentum	interacting collision carts
RSc	After observing two toy cars simultaneously entering and leaving cardboard tubes of different lengths, S must indicate (and justify) which car went faster.	coordination	speed	moving toy cars
RMd	After observing two balls of clay, establishing that they had the same amount of clay, and observing one of them being formed into the shape of a hot dog, S must indicate (and justify) that they still have the same amount of clay.	coordination	mass	balls of clay

* This table was prepared by the abstractor and represents some interpretation of the author's intent.

** This comment corrects an apparent typographical error which repeated the same requirement for the TPb and TSc tasks.

in the sense of equal representation of each task in each position (as would be the case with a Latin Square design for example). Furthermore, the individual task scores were combined in the analysis, making a Campbell and Stanley type diagram of the design used in the analysis inappropriate. To test the stated hypotheses, the data were analyzed separately for each of the three task dimensions with the factors of grade and sex not included. The design for this analysis of data was therefore that illustrated in Table 2 for the Inference Pattern dimension.

TABLE 2

REPEATED MEASURES DESIGN USED IN THE ANALYSIS OF DATA*

Factor (Dimension)	Inference Pattern		
Level (Value)	Compensation	Transitivity	Coordination
Subjects	1-160	1-160	1-160
	(CSa,CMa,CPb)**	(TSc,TMd,TPb)**	(RSc,RMd)**

*Similar designs were used with the other two task dimensions.

**The dependent variable was the combined score for the tasks sharing same value of the task dimension as indicated.

Analysis: The percentages of children at each grade level attaining a positive score on each task were determined and reported. Scores for tasks described by the same values of the task dimensions were grouped together and analyzed using analysis of variance techniques. The author reports that a multivariate analysis of variance was used but does not indicate what multiple dependent variables were employed. Planned comparison contrasts were used to test the significance of differences between groups of tasks for each dimension. The report does not specify how the contrasts were defined or what the reported degrees of freedom represent. The between subjects factors of grade and sex were apparently not used in this analysis of variance.

Findings

Although not included in the analysis of variance, inspection of the percentage data indicates that performance on all tasks improved consistently across grade levels. The analysis of variance indicated that all tested contrasts represented significant differences ($p < .001$). Thus, for the children tested, the level of performance differed for groups of tasks representing differing values on each of the task dimensions.

Interpretations

No direct statement concerning the disposition of the hypothesis is made although the implication is clear that they were supported. These results are viewed as showing "that achievement on the problems is a function of the dimensional nature of the tasks." The inference pattern result is interpreted as a result of the developmental sequence of the three types of operations required. The assertion is made that such differences would not be observed among individuals in the formal operational stage of development.

The author concludes that data on task performance should be viewed as a function of the configuration of the task dimensional values selected and not as an absolute characteristic of the value on any single task dimension. In particular, he states that failure to perform a given concept task does not necessarily imply that the learner cannot acquire the concept. In applying this conclusion to the work of Inhelder and Piaget, he suggests that problems such as those dealing with the inclined plane, inverse square law and centrifugal force might have been solved by younger children had the tasks been modified on one or more task dimensions. This point was not offered as a criticism of the work of Inhelder and Piaget, but rather as a caution in interpretation of their findings with respect to concept learning.

The author proposes that the relative difficulty indicated for the values of task dimensions be used in sequencing instruction. Specifically, he proposes that a "multidimensional matrix of task values within each of the dimensions" be constructed. The matrix would map out a range of tasks reflecting various levels of understanding of concepts. Such a matrix could be compared to a developmental scale of abilities to obtain information relevant to the placement and structure of curriculum content.

ABSTRACTOR'S ANALYSIS

Studies of the effects on performance of varying task dimensions are relatively rare in science education although many such studies have been reported in the experimental psychology literature (1). The present study may thus may be as important for bringing this approach to the attention of science educators as for the specific results it reports.

The present article is included in a cluster of reviews related to cognitive development. Its relation to the cognitive development literature can be clarified by distinguishing three types of cognitive development studies:

1. Studies describing or modeling the course of cognitive development.

2. Studies attempting to accelerate or promote cognitive development.

3. Studies taking developmental factors into account in research on instruction on tasks not themselves viewed as indicative of developmental level.

The first type of study uses observation of task performance as a basis for inferring the nature of underlying structures or processes in terms of which the developmental level of the individual is characterized. The children are not given instruction and the tasks are not representative of learning resulting from specific instruction. This type includes most of Piaget's own work as well as the study by Smedslund to which the present article refers. Smedslund's stated purpose was "to determine the interrelations of the specific acquisitions of ability for concrete reasoning, by means of a set of different test items" (11:27).

The second type of study assumes the validity of constructs characterizing the developmental level and uses task performance as a basis for inferring the level of individuals. Performance on such tasks is frequently used as the dependent variable in experiments in which children receive instruction designed to advance or accelerate development (e.g., Linn and Thier, 1975).

The third type of study is concerned with the relationship between developmental level and the effects of instruction on school learning tasks. Like the second type, these studies assume the validity of the constructs used to characterize developmental level and use performance on tasks to infer the developmental level of individuals. Inferences are then made about the learning patterns to be expected from given instruction. Frequently developmental level is used as a blocking variable or covariate with some measure of learning as the dependent variable. In an analysis of research on concept learning, Voelker (12) argues that science educators should place greater emphasis on this type of research. He proposed the development of a taxonomy of science concepts to guide such research.

Although the present study did not involve instruction and did use tasks similar to those frequently used in the first two types of study, it is more appropriately included with the third type. The tasks are considered to be potential candidates for inclusion in curricula designed to teach concepts. Raven seems to echo Voelker's recommendation by proposing the development of a matrix of conceptual task dimensions. The matrix would map out important aspects of potential instructional tasks. Knowledge of development could then be consulted in making decisions concerning selection and placement of tasks in curricula. If coordinated, Raven's proposed matrix and Voelker's proposed concept taxonomy might be highly complementary.

Two important questions arise concerning the interpretations of the results of the study. First, the major purpose of the study was to assess the validity of a dimensional representation of a set of concept tasks. The intended use of the task dimensions is to characterize many tasks, not just those in the present study. Since no qualification is made on the generalization of the findings to other tasks, the representativeness of the eight tasks selected becomes very important. Are they representative of the 36 categories generated by the defined dimensional values? The author does not indicate how the tasks were selected. If the tasks do not represent random selections from the values for each dimension, then generalizability to the set of 36 tasks is in doubt (fixed effects vs. random effects). There appears to be no basis at all for generalizing the findings beyond the range of values treated in the present study.

A second question arises from the analysis of data. Do the obtained differences among combined scores for groups of tasks provide convincing evidence of the dimensionality of the tasks? Additional evidence might be obtained by examining individual tasks. Smedslund (11:27) argues that only when all dimensions except one are held constant can the effects of that dimension be assessed. Figure 1 indicates that in the present study, four comparisons meet this criterion. Three of these compare different inference patterns while controlling for goal object and percept. Performance on compensation was better than that on transitivity for momentum and percept b. This pattern also held for the two cases where only goal object was held constant. Coordination performance was superior to transitivity for mass and percept d but was almost identical to transitivity for speed and percept c.

Statistical tests of these differences cannot be made with the reported data. However, assuming that the two differences just cited are significant, the evidence for dimensionality of the tasks appears mixed. This result is consistent with Smedslund's. He concluded "that the generality of overt observable inference patterns over goal objects and percepts is quite limited" (11:27).

The article could have been improved by inclusion of the additional information indicated in the abstract (the positive scores assigned to correct responses, the method of selecting the tasks to be used, the method of combining scores for groups of tasks, and explanations of the contrasts examined, the degrees of freedom reported and the multiple dependent variables). In addition, a number of other questions need to be answered for the reader to have a complete picture of the analysis of data and be able to assess its appropriateness: What error term was used in the analysis of variance? Was the analysis of variance for repeated measures employed? Was the reuse of the same data accounted for in the interpretation of the alpha level?

Another useful addition to the article would have been precise definitions of the task dimensions and values. Such definitions would help the reader to assess the appropriateness of the tasks used and to identify other appropriate tasks for further research. Why, for example, does inferring the relative number of bricks on the collision carts in the CPb task represent a momentum goal object? Also, Raven's coordination task for mass (RMd) is sometimes used as an indicator of ability to conserve quantity or substance (10). Is the coordination inference pattern similar or identical to the conservation inference pattern? Elkind's analysis of the conservation task (4) is an example of the kind of definition required for systematic cumulative research efforts such as that proposed by Raven

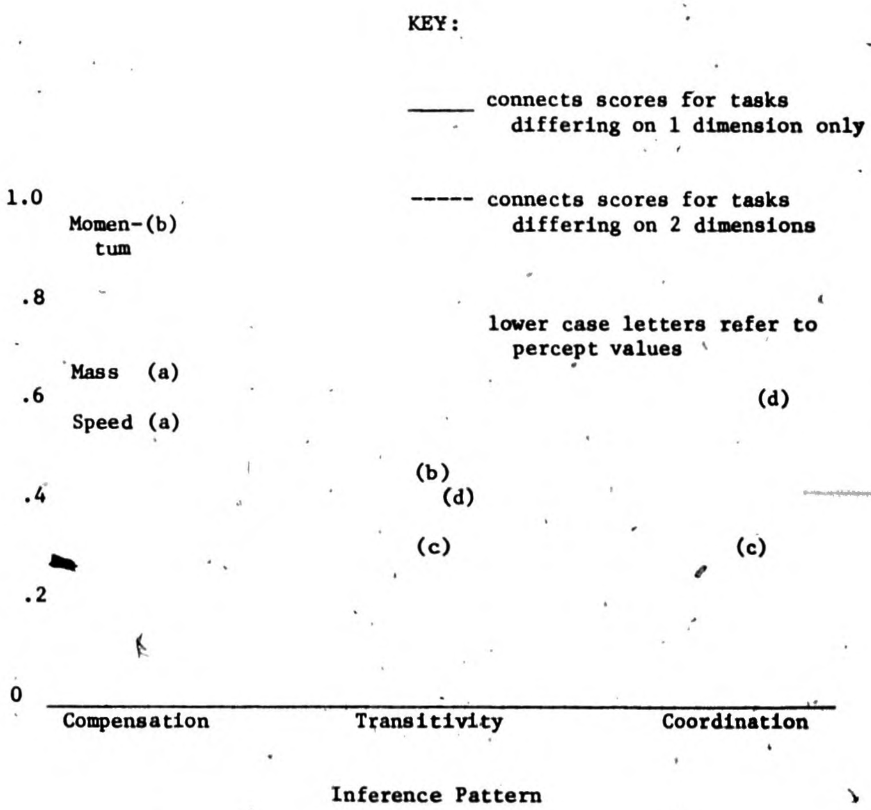

Figure 1 -- Graphic Comparisons Among Mean Task Scores

in the present article. Siegel and Hooper's collection of research based on Piaget's theory is an excellent source.

Proposals for systematic research on a given topic or within a given framework abound in science education. For such proposals to get off the ground, a long range commitment by researchers is necessary. If the proposer is not willing to make such a commitment, no one else is likely to either. The success of the present proposal for development of a task dimension matrix will also depend on the development and use of precise definitions of task dimensions, values and tasks.

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EJ 060 340

Allen, Leslie R., "An Evaluation of Children's Performance on Certain Cognitive, Affective, and Motivational Aspects of the Interaction Unit of the Science Curriculum Improvement Study Elementary Science Program." Journal of Research in Science Teaching, Vol, 9, No. 2: 167-173, 1972.

Descriptors--*Attitudes, *Cognitive Development, *Evaluation, *Elementary School Science, Grade 2, *Motivation, Science Course Improvement Project

Expanded Abstract and Analysis Prepared Especially for I.S.E. by Roger Cunningham, The Ohio State University.

Purpose

This study sought to determine if the physical science unit, Interaction and Systems, from the Science Curriculum Improvement Study (SCIS) is meeting its objectives by comparing nonparticipating second grade children with those studying the SCIS curriculum. A long range purpose is to produce information to be used in guiding curriculum decisions.

Rationale

This is the second phase of a longitudinal (six-year) study with this science program and its objectives as a focus. Nearly the same population had been used in the first study, "An Evaluation of Certain Cognitive Aspects of the Material Objects Unit of the SCIS Elementary Science Program," Journal of Research in Science Teaching, Vol. 7, pp. 277-281, 1970. Allen sought in this second study to look at the strength of cognitive, motivational and affective factors and their interaction with the variables of sex and socio-economic status. The primary concern was with measuring children's understanding of the terms "Interaction" and "Evidence of Interaction."

Research Design and Procedures

In the initial study a random sample of 50 children for each of the three predetermined socio-economic levels was drawn from the population of first grade children in the Honolulu, Hawaii, Schools participating in the SCIS program. Socio-economic status was determined by teacher judgement and family income criteria. Each of the SCIS schools was matched with a non-SCIS school of approximately equivalent socio-economic levels and the same number of first grade children were randomly selected from this population. Therefore, a total of 300 subjects participated in the first study.

In this second study 213 of the original 300 first grade children, 101 SCIS second graders and 112 non-SCIS second graders, participated. A fourteen item post-test was administered to these 213 second grade children. The focal objectives from the Interaction and Systems Unit were: (a) to recognize changes that occur during an experiment; (b) to understand and use the word "interact"; (c) to understand and use the phrase "evidence of interaction"; (d) to use various senses in gathering evidence of interaction; (e) to recognize evidence of interaction-at-a-distance.

In view of these objectives the test items were divided into three sets. Set one dealt with favorable attitudes toward science and the scientific process. Set two questions focused on identification of interaction as evidenced by changes produced in liquid crystals when influenced by objects manipulated by each child. The third set asked the child to note evidence of interaction and recognition of changes in a burning candle system as evidence of interaction. A record was kept of the number of SCIS children who understood the terms "Interaction" and "Evidence" as reflected by their not requiring definition of these terms.

Student responses to the fourteen items of the three sets were intercorrelated and factor analyzed by the principal axis method. The three factors were extracted and rotated to a Varimax Criterion. Factor one, considered a cognitive factor, consisted of seven items which dealt with recall or recognition of knowledge and the development of intellectual skills. Factor two, considered a motivational factor, included four items that required thought beyond the immediate task presented to the child. Factor three, identified as the affective factor, included items interpreted to reflect interests and attitudes.

Findings

The experimenter reports that recordings of the number of times the SCIS children understood the terms "Interact" and "Evidence" revealed that the children comprehended these terms in no less than 85 percent of the cases. He also reports that these terms had to be defined for all items in the evaluations for the non-SCIS children.

The average correlations between each item and its scale total (determined from the factor loadings) were 0.63 for the affective, 0.60 for the cognitive and 0.78 for the motivational factors respectively. To compare the SCIS with the non-SCIS performance, the factor scores were calculated on a 3-way analysis of variance carried out for each factor. Correlations between the post-test evaluations and the California Test of Mental Maturity were not used as a covariate because they were too low.

Factor one with a between treatment F ratio of 68.1 reportedly shows that the probability that this result could have been achieved by chance is low. Therefore, Allen concludes that the cognitive performance of the SCIS children is significantly superior to that of the non-SCIS children with 35 percent of the test variance accounted for through a ω^2 calculation. However, the same calculation for the affective factor explains only 2 percent of the variance despite a determined statistical difference between groups for this factor. The researcher claims significant differences in cognitive performance among the three socio-economic levels. However, these data were not given. No significant difference was determined between SCIS and non-SCIS children on the motivational factor.

Interpretations and Conclusions

According to Allen, approximately 90 percent of the SCIS children tested understood by responding to questions using the terms "interaction" and "evidence of interaction." Therefore, he concludes that the objectives for the Interaction and Systems Unit appear to be met satisfactorily. Honolulu, Hawaii, second grade children studying the SCIS program are statistically superior to non-SCIS children in both cognitive and affective behavior categories when the input variables of science program membership, sex and socio-economic status are used as criterion measures. However, only in the analysis of cognitive scores, with 35 percent of the variance accounted for, is there a strong statistical association between dependent and independent variables. Therefore, the researcher concludes that while the SCIS program is producing cognitive behavior of some practical significance for the classroom teacher, affective and motivational performance appears to be no better than that of the comparison group.

ABSTRACTOR'S ANALYSIS

Reactions to this investigation are tempered by the understanding that this article describes only a segment of the total study. The longitudinal nature of this research gives it a quality dimension. A long term look at the development of a select group of subjects, their performance with the focus science program (SCIS) and the long term effect of this program has merit. The use of a comparison group adds power to the study. However, the design and research procedures of this particular segment of the research present some questions and shortcomings.

One shortcoming is in the description of the sample population tested and the sampling procedures. The method of determining socio-economic status was likely influenced by teacher bias. It seems that family income indices would have been sufficient and more accurate for this determination. It is not clear why the researcher used matching by schools rather than by subjects. However, the use of matching never assures the researcher that differences between groups on the post-test measure are exclusively the result of an experimental variable.

In addition, no information is available in the report on the nature of the classrooms, the training of the teachers, their familiarity with the programs or the kinds of learning experiences engaged in by the students during the year. Neither does there seem to be a sufficient look at the students, their abilities and their interactions with the programs. One might assume that the children in the non-SCIS group were exposed to fewer "hands on" science experiences throughout the year. An even stronger bias against the non-SCIS group is possible because of the kinds of experiences they did or did not have.

It is possible they did not have physical science experiences of the type engaged in by the SCIS group. Does this study show no more than that children who are using the terms "interaction" and "evidence" with regularity are more familiar with these terms? The control group received nothing but the outcome test, not even training in the vocabulary which was central to the outcome measure. Thus on the one hand the finding that the SCIS group does better is in one respect trivial. On the other hand, the fact that these students can apply these terms to other tasks is not trivial. However, one has to raise the question as to whether the difference between the performance of the control and experimental groups on the cognitive objectives is due to program differences or familiarity or lack of familiarity with the terminology. The use of the terms as evidence of cognitive output might be questioned. Although loading is evident in the factors tested, why and in what way is not described in the report. In all fairness to the investigator, this may be a consequence of the research reporting procedures required by the journal rather than an oversight.

The researcher does not state any null hypotheses. For the analysis and the interpretation of the analyses to be clear the hypotheses being tested should be stated. Multivariate hypotheses are stated in a particular manner. Therefore, for this study to be useful to someone interested in replicating it, their absence presents a limitation. Although the instrumentation used in the investigation is adequately described, no mention is made of the reliability and validity coefficients. A reader unfamiliar with the instrument is at a loss to determine its true value as used in the investigation. A major source of invalidity could lie with the absence of a reliability coefficient for the test instrument. If the measuring instrument is not reliable, a true treatment effect may well be cancelled by the inconsistency or fluctuation of the instrument. In other words, a type II error will occur more often.

The investigator does not reference to any of the research that has been done to test the effectiveness of the SCIS program or, for that manner, any other research that would clarify the problem of this study or support its rationale. However, in all fairness to Allen, some of this research has been reported since his study.

Although the experimenter has attempted to control for external validity by using random selection, questions must be raised about the appropriateness of the objectives selected and the validity of the test items for testing performance of these objectives. The affective and motivational objectives are not ones specified by the SCIS program. Therefore, the researcher is testing for an outcome not intended by the program developers. Secondly, one would have to doubt that the questions presented in the test instrument are sufficient criterion measures for the affective qualities or that an adequate number of items were included for this determination.

Descriptions of the treatment are vague. The conditions and time period for the treatment and test are not described. This presents limitations for replication. A major source of invalidity is possible. The results are presented in a concise manner. The written description is consistent with the data and inferences are kept to a minimum and in terms of the results.

The author stated that significant differences in regard to cognitive performances existed between the three socio-economic levels. However, nothing is reported in the article that would substantiate this outcome. This also seems important for interpretation and replication of this study. The author also stated that 90 percent of the SCIS children tested understood and therefore were able to respond to questions involving the terms "interact" and "evidence of interaction." However, no explanation of the basis for this generalization is given. It is not clear in the article how the researcher kept track of student statements about interaction and evidence of interaction.

There appears to be no clear measure of attitudes toward the program experiences or test conditions. The motivational factor lacks clear definition. No significant differences for this factor is contradictory to previous studies on the SCIS program. There is no discussion of how the results of this study enhance or relate to making curriculum decisions as stated in the purposes.

Finally, in terms of most educational research, the amount of variance accounted for was determined to be 35 percent on the cognitive scores, which accounts for an appreciable portion of the variance, especially with such a large N.

EJ 126 602

Lawson, Anton E. "Sex Differences in Concrete and Formal Reasoning Ability as Measured by Manipulative Tasks and Written Tasks." Science Education, Vol. 59, No. 3:397-405, 1975.
Descriptors--Conservation (Concepts), *Critical Thinking, Educational Research, *Intellectual Development, Science Education, Secondary Education, *Secondary School Science, *Sex Differences

Expanded Abstract and Analysis Prepared Especially for I.S.E. by Elizabeth K. Stage and Fletcher G. Watson, Harvard University.

Purpose

This study was to assess the Piagetian level of performance of males and females on tasks of concrete and formal reasoning abilities and to answer the following questions:

1. Do males perform at a significantly higher (more formal) level than females on manipulative tasks of concrete and formal reasoning?

2. Do females perform at a significantly higher (more formal) level than males on a written examination of concrete and formal reasoning?

3. Overall, do males and females demonstrate significant differences in their ability to reason formally?

4. Do the manipulative tasks and pencil and paper examinations seem to be measuring different psychological parameters depending on the sex of the examinee?

Rationale

Previous investigation shows that males' and females' ability to demonstrate conservation reasoning may differ with respect to the format of the testing situation. They may also differ in ability to demonstrate formal reasoning depending upon the format of the testing situation.

If significant differences are found by varying format, they should be taken into account when assessing the reasoning abilities of males and females. If different formats show one sex performing at a more formal level, then the question of why such a result is obtained should be raised.

Research Design and Procedure

Sixty-two high school students (31 male, 31 female) were randomly chosen from a required high school biology course. Ages of the subjects were a mean of 15.2 for both sexes and a range of 14.4-17.5 for males and 14.2-17.1 for females.

All subjects were given all instruments.

1. Standard Piagetian manipulative tasks

   a. Bending rods - control of variables
   b. Balance equilibrium - inverse proportion

2. Pencil and paper examination - adaptation of Longeot's test

   a. Proportionality (Early formal, IIIA)
   b. Propositional Logic (Fully formal, IIIB)
   c. Combinatorial analysis (Fully formal, IIIB)

3. Additional Measures

   a. Conservation of weight
   b. Volume displacement

Findings

1. Significant differences ($p < .02$) were found between the means of both manipulative tasks with males performing more formally than females.

2. Significant differences ($p < .10$) were found only on the means of Propositional Logic written tasks with males performing more formally than females.

3. Males conserved more than females on both weight and volume displacement tasks but the Chi square was significant ($p < .001$) for only the volume displacement task.

4. A factor analysis was performed to assess whether the two manipulative tasks and the paper and pencil task were measuring the same psychological parameter. For the group as a whole, only one factor was extracted which accounted for 48.7 percent of the variance. For males alone, only one factor was extracted which accounted for 49.9 percent of the variance. For females alone, in contrast, two factors were extracted, one of which accounted for 48.2 percent and the other 20.5 percent of the variance. The pencil and paper measures loaded substantially on the first factor while the manipulative tasks loaded substantially on the second factor.

Interpretation

The format of the testing situation differentially affected males' and females' ability to demonstrate concrete and formal reasoning abilities. Males performed significantly better than females on manipulative reasoning tasks. Lawson ties this to the argument that males are superior at cognitive restructuring tasks.

The factor analysis further indicated that format differentially affected males and female since only one factor emerged for males but two for the females.

The sex of the experimenter may have had an effect since all of the testing was done by males, and other experimenters have found that this may yield superior male performance.

Males were also superior on conservation reasoning ability. Lawson ties this to the male cognitive style of field independence.

ABSTRACTOR'S ANALYSIS

Overall, Lawson's study seems well designed, carried out, and analyzed. The report is sufficiently detailed to allow for replication. The interpretation is the weakest component of the study

A minor objection is his use of $p < .10$ as criterion for statistical significance in the Propositional Logic component of the pencil and paper task. If that were not used, there would be no statistically significant sex differences on the paper and pencil task. This treatment would yield more support for his format differential argument and, more importantly, would mandate a more focused discussion of the relationship between format and the two factors on female performance.

The major interpretive criticism, however, is more general. There seems to be a certain naivete or bias on the part of the author with respect to the sex differences literature. Both the cognitive restructuring and the field independence argument are ones which, although not discredited entirely by Maccoby and Jacklin (1), have been put in a more narrow perspective. Males have been found to be superior in visual-spatial abilities by the age of Lawson's subjects. Maccoby and Jacklin have concluded that "Boys do not excel at tasks that call for 'decontextualization' or disembedding, except when the task is visual-spatial" (p. 350). In addition, "The sex difference in field independence is quite narrowly confined to visual-spatial tasks" (p. 105). Thus, if Maccoby and Jacklin are correct, cognitive restructuring and field independence differences are derivative from visual-spatial differences. And thus, Lawson should compare his differences at the level of analysis of the degree of visual-spatial ability required by the format. This sort of interpretation is consistent with his much less striking differences on the paper and pencil task.

Also, the fact that the investigation focuses on sex differences should have been sufficient warning that he should have used both male and female examiners for both male and female subjects in order to rule out the potentially interfering effect.

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PIAGETIAN STUDIES

EJ 020 351

Karplus, Elizabeth F. and Robert Karplus, "Intellectual Development Beyond Elementary School I: Deductive Logic." School Science and Mathematics, Vol. 70, No. 5:398-407, 1970.

Descriptors--*Intellectual Development, *Logic, *Learning, Physics Teachers, Puzzles, *Student Characteristics, *Teacher Characteristics

EJ 032 300

Karplus, Robert and Rita W. Peterson, "Intellectual Development Beyond Elementary School II: Ratio, A Survey." School Science and Mathematics, Vol. 70, No. 9:813-820, 1970.

Descriptors--*Elementary School Science, *Learning, *Mathematical Concepts, *Ratios (Mathematics), *Secondary School Science, Cognitive Processes, Evaluation, Logical Thinking, [Piaget (Jean)]

EJ 067 212

Karplus, Robert and Elizabeth F. Karplus, "Intellectual Development Beyond Elementary School III: Ratio, A Longitudinal Study." School Science and Mathematics, Vol. 72, No. 8:735-742, 1972.

Descriptors--*Cognitive Development, Elementary School Mathematics, Learning Theories, Longitudinal Studies, *Mathematics Education, Mathematical Concepts, *Ratios (Mathematics), *Research, Secondary School Mathematics

EJ 106 393

Karplus, Elizabeth F. and Others, "Intellectual Development Beyond Elementary School IV: Ratio, The Influence of Cognitive Style." School Science and Mathematics, Vol. 74, No. 6:476-482, 1974.

Descriptors--*Learning Characteristics, Learning Theories, *Mathematics Education, *Ratios (Mathematics), *Research

EJ 108 007

Wollman, Warren and Robert Karplus, "Intellectual Development Beyond Elementary School V: Using Ratio in Differing Tasks." School Science and Mathematics, Vol. 74, No. 7:593-613, 1974.

Descriptors--Cognitive Development, Grade 7, Grade 8, Instruction, *Learning, Mathematics Education, *Ratios (Mathematics), *Research, *Secondary School Mathematics

Expanded Abstract and Analysis Prepared Especially for I.S.E. by John A. Easley, Jr. and Kenneth J. Travers, University of Illinois-Urbana.

Purpose

This series of five studies by Karplus and his associates at the University of California-Berkeley, investigated the conceptual development of children in the upper elementary grades and high school, and (in one study) of adults. Using the group test, the experimenters classified responses according to a hierarchical schema, with categories ranging from concrete to abstract levels of thought. The studies were intended to reveal information as to how well certain concepts, primarily that of ratio, function at various ages and to explore conditions under which learning of these concepts might be facilitated. Implications of the findings for mathematics and science curricula were also discussed.

Rationale

The concepts of ratio and proportion are essential to an understanding of quantitative relations in science, as for example in many mathematical models. Hence, it is important that educators and researchers learn methods for determining the extent to which concepts, such as ratio, have been attained. Furthermore, curriculum developers ought to have at their disposal methods for identifying areas of need among students at various age and grade levels. The studies also sought to shed light on what tasks or techniques appear to promote concept acquisition and what learnings have accrued from various curricula. The possibility of cross-national comparisons of concept learning was also suggested. The use of group testing techniques (as opposed to clinical interviews) for assessing knowledge would make possible large-scale investigations of the questions addressed by Karplus' research.

The research appeared to have its point of departure in that of Inhelder and Piaget (4), which defines a stage of formal operations and links proportional thinking to this age. [However, these studies of intellectual development also relate to work by Lunzer and Pumfrey (8), Lovell and Butterworth (9), and Dienes (1). A review of these and other studies purporting to deal with formal operations was presented by Lunzer (to appear) at the 1973 meeting of the Jean Piaget Society (see Abstractor's Analysis below).]

Research Design and Procedure

The distinguishing features of the five studies are summarized in Table 1. Each study is subsequently referred to by the Roman numeral appearing in the title (e.g., "III" refers to Karplus and Karplus, 1972).

The five studies had similar designs in that each consisted of the administration of a task, an analysis and classification of Ss' responses to the task, a tallying of the responses in the various categories, and a discussion of the resulting data.

TABLE 1

Tasks Used in the Five Studies

Study	I	II	III	IV	V
Name of task and required completion time	Island Puzzle (10-15 min.)	Paper Clips Form A (15 min.)	Paper Clips Form A (15 min.)	Paper Clips Form B (15 min.)	*Paper Clips Form B (15 min.) *Candy (15 min.) **Ruler (2-4 min.) **Pulley (4-8 min.) *Workbook (20 min.) geometry arithmetic
How administered	Group	Group	Group	Group	*Group **Individual
Subjects used	Six groups (N = 449) from grade 5 through adult (teachers of science)	Six groups (N = 727) from grades 4-12, urban and suburban	Grade 6, 8, and 11 suburban students tested in study II as grade 4, 6, and 9 (N = 155) plus new group of grade 8 students (N = 141)	Grades 4-9 urban and suburban (N = 616)	Grades 7-8 students suburban (N = 450)

Brief Description of Tasks Used

Island Puzzle: This puzzle involved four islands in an ocean and the possibilities of travel between them. The task was designed to assess abstract reasoning ability. Individual responses were written.

Paper Clips, Form A: Ss each were given a sheet of paper on which a stick figure 7 9/16 inches tall was drawn, together with a chain of from seven to ten No. 1 "Gem" paper clips. Ss were shown a display chart with the same figure as they had on their sheets, with a scaled up version on the back side of the chart. The experimenter had a chain of eight jumbo paper clips. Ss were shown that the small figure was four "biggies" (jumbo paper clips) tall and the large figure was six "biggies" tall. Ss were to measure the small figure on their sheets with "smallies" (small paper clips) and to predict the tall figure's height in "smallies." Ss wrote their responses.

Paper Clips, Form B: This was similar to Form A, with the important difference that Ss did not ever see the tall figure. Ss were told that the small figure was four buttons tall and the large figure was six buttons tall. They were to measure the small figure in paper clips and predict the height of the large figure in paper clips.

Candy: Ss were given written information concerning a person who had many bags of two kinds of candy, each bag containing a certain number of reds and a different certain number of yellows. All bags were alike. Ss were given written information relevant to predicting the number of candies taken from the bags. One task (a) involved application of the ratio 5:3; the other (b) involved the ratio 2:1.

Ruler: An individually administered task was used, involving an unmarked rod and a ruler marked in both inches and centimeters. Ss were shown that a displacement of 2 inches on the rod was equivalent to a displacement of about 5 cm. Ss were then asked how many centimeters would be equivalent to a displacement of 8 inches.

Pulley: Individuals were interviewed using a mechanism which involved two pulleys (diameter ratio 3:2) fixed to same shaft, a string attached to each pulley, and a meter stick. S and experimenter worked together on the mechanism and S was shown that a displacement of 10 cm. on his or her string corresponded to a displacement of 15 cm. on the experimenter's string. S was then asked how far the experimenter's string would move when S's string was displaced 6 cm. and to explain why.

Workbook: Two tasks were designed to be similar to those found in textbooks. One geometrical task was intended to assess the S's ability to recognize a fraction of a whole and to represent this faction pictorially and numerically. The other task, numerical, required the S to apply proportional reasoning with no circumstantial clues.

Categories Used to Analyze Tasks

Study I:

N	(no explanation)
I	(prelogical)
IIa	(transition to concrete)
IIb	(concrete)
IIIa	(transition to abstract logic)
IIIb	(abstract logic)

Studies II-V:

N	(no explanation or statement given)
I	(intuition): estimates, guesses without reference to data
IC	(intuitive computation): data used haphazardly or illogically
A	(addition): uses difference rather than ratio
S	(scaling): uses change of scale, not related to scale inherent in data
AS	(addition and scaling): use of difference and scaling
IP	(incomplete proportion): uses one ratio only
P	(proportional reasoning): uses properties of proportionality 3 subcategories of P: PC (proportion, concrete) AP (addition and proportion) R (application of ratio)

Findings

All five studies revealed a tendency for the median frequency of tasks to move from the lower level categories (such as I and S) to the higher categories (such as P) as the grade level of the respondents increased. Wide fluctuations in performance within grade levels were found in II. In one urban class, 90% of the responses were placed in categories N, I, or IC, while in another class, categories AS and P were more numerous than in any one suburban class. In III, a longitudinal design produced data suggesting that the categories may be representative of developmental levels. Of the 153 students involved in the two-year study, 28% moved into P or AS, while only one student moved out from P to A. At the lower levels, 7% moved from other categories into I or IC, while during the same two-year period, 65% moved out. It was also found, however, that 40% of the students remained in their categories for both testings.

Table II, which combines the categories into three levels, summarizes the classification of the Ss in study III over 2 years (1969 and 1971).

TABLE II

Matrix Comparing Students in 1969 and 1971 by Levels

(Number of Students)

1969	1971			
	Level I	Level II	Level III	Toaal
Level I = I + IC	19	22	10	51
Level II = S + A	7	45	26	78
Level III = AS + P	0	1	23	24
Total	26	68	59	153

(From Karplus and Karplus, 1972, p. 739)

Study IV used a new form of the Paper Clips Task. It was more abstract than Form A, in that the S did not ever see the figure whose height was to be predicted using a proportion. A dramatic reduction was found in the number of Ss' (scaling) responses to Form A (30%) when Form B (4%) was used, with a corresponding increase in categories IC, IP, A, and P. The latter categories require, the researchers assert, conceptual processing of the data by the Ss (IV, p. 480).

The variety of tasks used in V proved to be interesting. Results on Form B of the Paper Clips Task were similar to those obtained by the 8th graders in IV. Sex differences in responses were not appreciable. It was found that the value of the ratio used is a factor to be taken into account. In the Candy Task, application of an integral ratio (2:1) was interpreted as not indicative of formal reasoning, since use of the ratio did not correlate with proportional reasoning in a more complicated task (V, pp. 597-598). The Ruler Task was found to be easy for the junior high school students, since 87% responded with proportional reasoning. The Pulley Task was more difficult and the geometrical and numerical items were most abstract (V, p. 604). It was noted that a perfect score on the numerical items was a good predictor of success on the geometric items, while the reverse did not hold.

Interpretations

The researchers, overall, were disturbed by the implications of their findings. In study I, intellectual development, as assessed by their taxonomy, reached a "disappointingly low level" in the high school age group and did not progress much further (I, p. 403). In study II, it was found that successful proportional reasoning was not reached until the last years in high school. This concern was reiterated in III, where evidence was found that many students did not advance to more abstract categories of thought during the intervening two years of that longitudinal study. Another disturbing implication, prompted by the data of studies II and III, was evidence of apparent obstacles to learning which may be inadvertently set up by "mathematics courses, by teachers, and by the children's cultural environment" (II, p. 817). Of particular notice was the dramatic contrast between the responses of urban and suburban 11th and 12th grade students. It was found that 80% of the suburban students, but only 9% of the urban students, were classified at the highest level P.

The findings of study IV placed emphasis on the context in which the problem was presented. Since Form B of the Paper Clips Task was more abstract than Form A, the researchers concluded that Form B compelled the students to make use of the data. Indeed, they concluded, Categories I and S under Form A (studies II and III) may reveal an attitude toward handling of the data rather than the respondent's cognitive level of competence (IV, p. 480).

The variety of tasks used in V led the researchers to generalize about the influence of a task upon the S's response. Tasks tending toward concreteness (Ruler, Paper Clips) led to more correct responses than did the abstract tasks. The lack of applicability of proportional reasoning to physical relationships raised questions about the appropriateness of many instructional strategies, particularly at the junior high school level, where only about 15% of the subjects were found to have reached the highest level. The researchers speculated that one source of the problem may be that ratios are introduced as fractions and proportions as equivalent fractions. "Curricula make little effort to interpret ratio, proportion, and the related division process in terms of . . . correspondences of measurements. In this use of division, the concept of remainder has no place" (V, p. 610).

ABSTRACTOR'S ANALYSIS

It should be clearly noted that Karplus and his colleagues are investigating a different problem from that studied by Piaget. It is easy to lump these together with all kinds of studies involving tasks that can be called "formal reasoning," by the ordinary meaning of that term. Lunzer (7), for example, made no notice of the peculiar use Piaget and the Geneva School make of that term, but made a broad survey of problem-solving studies in which logic or other formal rules or procedures were used and made it the basis for a critique of Piaget's theory of the stage of formal operations. Karplus and his collaborators are careful not to identify what they call proportional reasoning in studies II-V and what they call "abstract logic" in study I, with Piaget's Formal Operations. At least, they are quite open to the possibility that these may turn out to be different things. The situation is reminiscent of one involving the notion of relative motion.

When Piaget argued that understanding relative motion required the INRC group, and hence was a formal level task, Easley (2) attempted to provide an operational definition of the INRC group in the snail board problem Piaget had used in his studies of relative motion. However, Piaget made it quite clear that young children who could perform in a way that satisfied that operational definition would not thereby automatically be credited with having achieved the formal level (personal communication). Here in the studies under review, we have evidence from high school seniors (and even many adults) who do not employ "abstract logic" or "proportional reasoning" in these problems, but we are not entitled to infer that they have not achieved the stage of formal operations, as Piaget defines it, even though Inhelder and Piaget state that proportional reasoning is only attained at the stage of formal operations.

Piaget's theory, briefly, is that four cognitive structures called logical operations (identity, negation, reciprocity, and correlation), usually between the ages of 10 and 14, unite to form a single structure, the INRC group. This greatly increases the power of the individual over the intuitive feelings of physical quantity operations. Thus, Piaget writes:

> It seems evident, in the instance of weight, that the difficulties of dynamic interpretation presented by this motion play a big role in the delay of its operational structuration, because of the contradictions that must be overcome between the demands of structuration and the diversity of objective causal situations. The same applies to volume, the delayed logicalization of which seems to be linked to geometric problems of internal continuum . . . going beyond the realm of concrete operation (11:3).

Second, the group composition of the individual operations now permits operations on operations, which supports the development of proportionality. Thus Piaget writes:

> But we have also seen how the subject succeeds (first) in constructing by reflexive abstraction his multiplicative operations as additive operations at the second power, then his structures of proportionality by equalization of relationships (therefore, again, by relationships of relationships or relationships at the second power) . . . (11:67).

To discover whether a subject has attained the stage of formal operations for proportionality operations in a given context, Piaget and his colleagues employ the clinical interview with probing (at times, prompting the subject first in one direction and then in another to separate any efforts to please the interviewer from what the subject genuinely believes) and continuing the probing until satisfied that the most advanced level of which the subject is capable has been demonstrated.

They thereby incur the criticism of behaviorists that they are leading and prompting their subjects. However, Piaget argued (10) that without such methods they cannot discover intellectual structures.

On the other hand, Karplus and his colleagues are interested in the primary or spontaneous level of thought (defined in terms of their categories) that subjects employ when solving a paper-and-pencil test. Although they state that they have used interviews to check the levels of performance they get on paper-and-pencil tests, it is clear that they have avoided the clinical interview with its probing and prompting. This difference in purpose and procedure explains in part the differences in age distribution found between the two groups of studies. A second major contribution to these differences, which the research to date cannot isolate from the first, is the phenomenon Piaget calls decalage (separation or displacement). This refers to the delay in development from the first case in which a subject can use a given form of thought (in this case, formal operations) to a more difficult application that is different in content. While Piaget's theory of decalage is not very well developed, the essay quoted above [Piaget (11)] indicates that the developmental relationships between various kinesthetic structures and logical ones is complex. Another difference is that Karplus et al. (study V) employ a concept of types of reasoning which depends on the external static form of arguments. This contrasts sharply with Piaget's interest in internal dynamic processes [see Easley (3)].

The gulf between the narrow conceptual and methodological traditions that characterize these two groups of studies has not yet been bridged. Both groups have legitimate research interests and both have practical applications to education. It is interesting, for example, that the Elementary Science Study and the Science Curriculum Improvement Study, the latter of which is directed by Karplus, have generally been interpreted as attempting to challenge the highest intellectual competence. of children and not merely tap their typical performance in a situation. It might seem then that Piaget's approach to research on cognitive development could be more relevant to Karplus' elementary school project than Karplus' own research approach is, or perhaps that, in preparation for the development of new secondary school curricula, a more external form is thought to be required. Perhaps there is another reason we do not understand for the maintenance of this separation.

The issues raised by this series of studies are important ones. Other mathematics educators will surely share the investigators' concerns over the appropriateness of the current curriculum (and its typical method of implementation) for developing applications of mathematics to real-world problems. If it can be agreed that the mathematics curriculum should indeed promote creative use of numbers to describe physical objects (as is required in the sciences), then a research base for curriculum development in integrated mathematics and science programs is an important emphasis for future study. Also, despite the difference between Piagetian clinical interviews and Karplus' paper-and-pencil tasks, both offer alternatives to the conventional fascination with standardized (group-normed) tests of aptitude or achievement.

Karplus and his associates also raise the matter of cross-national comparisons of educational programs through an examination of intellectual develomment. Such a topic would appear to lend itself readily to consideration for inclusion in the proposed second round of school subject surveys by the International Association for the Evaluation of Educational Achievement. Information is needed on the relationship bttween different curricular emphases found in various countries and the attendant differences in conceptual development. Might it be the case that some countries are indeed much more successful than others in promoting the attainment of proportional reasoning for the majority of students during the junior high school or early high school years? In terms of Piagetian methods, recent suggestions that the rate of intellectual development might be uniform across cultures [Kamara and Easley (5)] is not well supported beyond the stage of concrete operations. Further research on this front is needed also.

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