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AUTHOR Lawson, Anton E.; Wollman, Warren T.
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ABSTRACT

An attempt to train concrete operational fifth-grade students (N=32) and seventh-grade students (N=32) to perform at the formal operational level on tasks demanding the control of variables are reported. The training was conducted in four individual sessions of approximately 30 minutes each. The training sessions were designed to represent a synthesis of ideas concerning the mechanisms of development put forth by Piaget, Ausubel, Bruner, and C. Lawson. The training was successful ($p < .001$) and specific transfer of the trained concept was obtained for both samples. Pretest level of intellectual development was significantly related to success on posttest tasks of specific transfer ($p < .10$). On one posttest task designed to measure nonspecific transfer, the trained seventh-grade subjects scored significantly higher ($p < .05$) than the control subjects. The effectiveness of the training suggests that properly designed instruction, which is based on students' intuitive conceptual understanding at the concrete level, can raise this intuitive understanding to the level of a meaningful verbal rule which then can be successfully applied in a variety of problem situations. (Author)

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ENCOURAGING THE TRANSITION FROM CONCRETE TO FORMAL
COGNITIVE FUNCTIONING--AN EXPERIMENT

Anton E. Lawson and Warren T. Wollman
AESOP* Lawrence Hall of Science
University of California
Berkeley 94720--February 1975

Flavell¹ describes Piaget's stage of formal thought as:

...not so much this or that specific behavior as it is a
generalized orientation, sometimes explicit and sometimes
implicit, towards problem-solving: an orientation towards
organizing data (combinatorial analysis), towards isolation
and control of variables, towards the hypothetical, and
towards logical justification and proof. (p. 211).

Encouraging this type of orientation towards problem-solving is of utmost
importance to educators. As stated by the Educational Policies Commission²
the central purpose of American education is the development of problem-
solving processes called rational powers.** The parallel between the ra-
tional powers and the problem-solving processes utilized by formal thinkers
is clear.***

One must not be misled to interpret Piaget's theory as implying that
maturation of the nervous system is sufficient for the development of formal
thought. If this were the case the job of our educational system would be
small indeed. Rather, maturation only determines the totality of possibil-
ities and impossibilities at a given stage. As Inhelder and Piaget⁴ state:
"A particular social environment remains indispensable for the realization
of these possibilities. It follows that their realization can be accelerated
or retarded as a function of cultural and educational conditions." (p. 237).
The finding, that formal thought is normally demonstrated by only about 50
percent of the subjects in most adolescent and even adult samples which have
been studied in this country, suggests a very real educational problem.^{5, 10}

Little is presently known about specific factors and how they interact
to contribute to and affect the transition from concrete to formal cognitive
functioning. Piagetian theory itself only provides a general view. At best
Piaget's factors of neurological development, social transmission, experience
with things, and internal cognitive reorganization (equilibration) are sug-
gestive but not sufficient to provide sound instructional theory. How can
these factors be interrelated to facilitate formal or abstract thought?

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**The rational powers are listed as the processes of: recalling and imagining,
classifying and generalizing, comparing and evaluating, analyzing and syn-
thesizing, and deducing and inferring.

***For an in depth discussion of intellectual and moral development as the
aim of education. See: Kohlberg and Mayer.³

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In a recent survey, Wollman¹¹ observed that students as young as second graders have, at least an intuitive notion of the formal idea of controlling variables. Piaget claims this idea is fully developed only during adolescence. Ausubel suggests that it might be possible to utilize prior intuitive understanding to facilitate learning and stabilization of more formal (abstract) conceptualizations during adolescence.¹² In the same vein, Bruner and Kenney argue that intellectual development begins with instrumental activity, a kind of development by doing.¹³ They suggest that these activities become represented and summarized by individuals in the form of particular images. Further with the aid of symbolic notation that remains invariant across transformations in imagery, the learner gradually becomes aware of the formal or abstract properties of the things he is experiencing. These findings and statements suggest that it might be possible to design instructional sessions which will enable students who are in Piaget's stage of concrete operations to function at the formal operational level, with respect to specific concepts. However, as Ausubel states: "If stages of development have any true meaning, the answer to this question [can training enable children to acquire genuine appreciation of concepts which are normally acquired only at advanced stages of development?] can only be that although some acceleration is possible it is necessarily limited in extent."¹⁴ (p.264).

Problem Statement

This investigation, then, addressed itself to the following questions: (1) Can instructional procedures incorporating the above ideas be designed, and employed to successfully affect the transition from concrete to formal cognitive functioning in fifth grade and seventh grade students with regard to one aspect of formal thought, i.e., the ability to isolate and control variables? In addition to this question the following, related issues were addressed: (2) If training can enable concrete students to perform at a formal level on tasks which were used in the training phase, will this training transfer to tasks also involving the control of variables but using novel materials? This is termed specific transfer.¹⁴ (3) If training can enable concrete students to perform at a formal level on tasks requiring the control of variables will this training transfer to tasks involving different concepts but ones which also involve formal thought (nonspecific transfer): In other words, if the training was effective, was it limited to the specific concepts involved or did it affect a more general shift from concrete to formal cognitive functioning? (4) What is the relationship between a student's level of intellectual development and his ability to profit from the training?

Method

Subjects

Thirty-two fifth grade students and 32 seventh grade students enrolled in an elementary school and a junior high school in Lafayette, California served as subjects. The fifth grade students (14 males and 18 females) ranged in age from 9.5 years to 12.1 years, mean age = 10.5 years. No IQ data was available for these students. The seventh grade students (16 males and 16 females) ranged in age from 11.9 years to 13.6 years; mean age = 12.6 years and had IQ's which ranged from 100-115, mean IQ = 109. Lafayette is an upper-middle class suburban community in the San Francisco Bay Region.

Many studies, such as those mentioned previously, suggest that formal thought often does not develop during the general age guidelines of 11-15 years given by Piaget. It was, nevertheless, decided to work with students slightly younger or slightly older than the figure suggested as the age of onset of formal thought. If instructional procedures can successfully effect a shift from concrete to formal operational levels of thinking the ages of 10 to 13 may be the optimum time for such instruction.

Experimental Design and Procedure

The fifth grade study. The experimental design employed in this investigation is referred to by Campbell and Stanley⁵ as the pretest-posttest control group design. In effect, two separate investigations were conducted. In the first experiment the 32 fifth grade students were randomly placed into two groups of 16 students each--an experimental group which received training concerning the concept of controlling variables and a control group which did not receive training. Both groups of students were pretested in individual interviews with a battery of Piagetian tasks (conservation of weight, conservation of volume, volume displacement and bending rods) which allowed classification of the subjects into early concrete-IIA, late concrete-IIIB, post-concrete and early formal-IIIA levels of intellectual development. The experimental group subjects then participated in four sessions of individual training. Each session lasted about 30 minutes. The control group subjects attended their regularly scheduled classes during this time. The training sessions, which will be described in more detail below, involved the presentation of problems involving the determination of cause and effect relationships. The first session involved bouncing tennis balls, the second session involved bending rods materials used during the pretest, the third session involved an apparatus called a "Whirly Bird"¹⁶ and the fourth session involved two biology experiments presented in a pencil and paper format.

Posttesting of all 32 subjects followed the training sessions and was conducted in two phases. The first phase consisted of individual interviews conducted by two trained examiners who had no prior knowledge of which subjects were members of the experimental and control groups. A male examiner interviewed the male subjects and female examiner interviewed the female subjects.* Three Piagetian manipulative tasks (bending rods, the pendulum, and the balance beam) were administered. Each task allowed classification of subjects into concrete or formal operational levels of intellectual development. The bending rods task was used to determine whether or not the training was effective in facilitating the ability to control variables with materials identical to those used during the training. The pendulum task was used to determine whether or not the training was generalizable to a problem also involving controlling variables but using novel materials (specific transfer). The balance beam task was also used to determine the extent to which the training encouraged formal thinking. This task, however, did not involve controlling variables, rather it involved proportional reasoning. Piaget claims that this reasoning ability develops concomitantly with the ability to control variables. This task therefore could be considered as a measure of nonspecific transfer of

*Research such as that conducted by Brekke and Williams¹⁷ has shown that male subjects perform better on Piagetian tasks when the examiner is a male, likewise female subjects perform better when the examiner is a female.

training. In addition to the three Piagetian tasks students responded orally to a written question involving value judgment adapted from Peel.¹⁸ Responses were tape recorded and later classified into developmental categories.

During the second phase of the posttesting all 32 subjects were grouped together and two pencil and paper examinations were administered. Subjects responded to a spheres task¹⁹ involving the control of variables, a logic question involving the logical fallacy known as affirming the consequent, and one combinatorial question. These problems like the balance beam task and the Peel question, were administered to determine the extent to which the training encouraged a general shift from concrete to formal operational thinking rather than a specific shift limited to the control of variables. The spheres task, like the pendulum task, tested for specific transfer of the trained concept. It was, however, an additional step removed from the training in that it did not involve the manipulation of materials.

The seventh grade study. The experimental design employed and procedures described above were repeated using the sample of seventh grade students. The only changes made were on the posttests. It was decided to use a shortened version of the Longest examination^{19, 20} which incorporated problems of class logic, propositional logic, proportional reasoning, and combinatorial reasoning as the measure of nonspecific transfer of training. The Longest examination has been shown to be an effective instrument to measure general levels of concrete and formal operational thought.^{21, 22}

Pretests

Four Piagetian-styled tasks were administered to experimental and control subjects in individual interviews. All conservation questions were asked in a counterbalanced order. Since each task has been employed by previous investigators, only brief descriptions of the tasks and materials used are included.

Conservation of weight.²¹ Two balls of clay of approximately 50 grams each were presented S. One ball was then transformed into a pancake shape and S was asked about the relative weights of the balls.

Conservation of volume using clay.²³ The two balls of clay from the previous task were used. S agreed that two beakers (400-ml) contained the same amount of water and was asked about the relative amount of water displaced by the two pieces of clay.

Displacement volume.²⁴ Two metal cylinders of equal volume but different weight (18-g and 55-g) were handed S. The equal height and thickness of the metal cylinders were pointed out. S then took the cylinders and lowered the lighter one into one of two test tubes (30-ml) which were partially filled with equal amounts of water. The rise in water level was noted and S was asked to predict the rise in water level when the heavier cylinder was lowered into the other test tube.

subjects were classified into developmental levels as follows:

- Concrete-IIA. Nonconservation responses on all three tasks.
- Concrete-IIB. Conservation of weight and nonconservation of volume and volume displacement.
- Post-concrete. Conservation of weight and conservation of volume or volume displacement.
- Formal-IIIA. Conservation responses on all three tasks.

The bending rods task will be described in the section on posttesting below.

Training

Each subject (S) in the experimental groups met with an experimenter (E) for four 30-minute individual training sessions. The sessions were conducted over a period of approximately two weeks and took place in as reasonably quiet and private places as the schools could furnish. During the sessions S and E were seated at a table with the instructional materials in front of them.

Session I. The first session began by giving S a brief introduction to the intent and format of the training. S was told that a number of different kinds of materials would be used to try to teach him how to perform "fair tests." This coupled with the initial use of this term in the context of bouncing tennis balls was done to provide S with an intuitive feel for what the training was all about, in a sense to provide S with a "ball park" in which to work. In psychological terms it amounts to the "whole" which will later become differentiated (see Lawson²⁵). The materials used in this session were materials very familiar to children; three tennis balls (two which were relatively bouncy and one which was considerably less bouncy) two square pieces of cardboard, two square pieces of foam rubber and a table. S was told that the first problem was to find out which of the tennis balls was the bounciest. To do this S would instruct E in how to perform the experiment and E would carry out S's instructions. Although each session varied somewhat, in general S would begin by telling E to take two balls and drop them to see which bounced higher (height of bounce then became the dependent variable). E would then drop the two balls but drop them from different heights (an uncontrolled experiment). S would then respond by saying: "That isn't fair. Drop them from the same height." On the next trial the height would be equalized, however, one ball would be dropped so that it hit the table top while the other ball hit the floor (again an uncontrolled experiment). This procedure was followed by continually trying to intervene with new uncontrolled variables (spin one ball, push one ball, let one ball hit cardboard or foam rubber). S's were then told that a test was called a "fair test" if all the things (variables) that might make a difference were the same in both balls (except, of course, for the difference in the balls themselves). Each time a test was made in which these variables were not the same was called an "unfair test." Following introduction of those more general statements and terms, several additional examples were given and talked through.

The overall intent of this first session was to start with an undifferentiated whole (as suggested by Lawson²⁵), capitalize on the subject's intuitive understanding (as suggested by Ausubel¹²), provide numerous particular images (as suggested by Bruner and Kenney¹³), provide contradictions (as suggested by Piaget²⁶) and provide symbolic notation (the phrases "fair" and "unfair tests") which remained invariant across changes in imagery—provided by the materials used in the subsequent sessions-- (also suggested by Bruner and Kenney, and by Lawson, Blake, and Nordland²⁷).

Session 2. The second session began by reminding Ss of the intent of the training and by pointing out the new materials. The materials were those used for the bending rods task administered during the pre- and post-testing. Six metal rods of varying size, shape, and material were placed on the table and S was asked to classify them in as many ways as possible. This was done to determine Ss ability to form the classes of size, shape, and material and to insure that these differences in the rods were noted. The rods were then placed into a stationary block of wood and all the factors (variables) which might affect the amount of bending of the rods (the dependent variable) were discussed. S was then asked to perform "fair tests" to find out if the variables of length, thickness, shape, and material of the rods, as well as the amount of weight hung on the end of the rods affects the amount the rods will bend. Whenever S performed a test he was asked: Is this a fair test? Why is it a fair test? Can you be sure that this rod bends more than that one are only because it is thinner. Is there any other reason (an uncontrolled variable) why it might be bending more? These questions and others were used to focus Ss attention on all the relevant variables and recognize unambiguous and ambiguous experiments in an attempt to lead them to understand the necessity for keeping "all factors the same" except the one being tested to determine causal relationships. A number of examples and counter-examples were discussed at length. The concepts involved in this session were identical to that of the first, the material (the context) however, was different.

Session 3. At the outset of the third session Ss were asked to experiment with an apparatus called a Whirly Bird.¹⁶ The Whirly Bird consists of a base which holds a post. An arm is attached to end of the post. When pushed or propelled by a wound rubber band, the arm will spin around like the rotor on a helicopter. Metal weights can be placed at various positions along the arm. Ss were briefly shown how the Whirly Bird worked and were given the task of finding out all the things (variables) which they thought might make a difference in the number of times the arm would spin before it came to rest (the dependent variable). Possible variables included the number of times the rubber band was wound, the number of rubber bands, the number of weights placed on the arm, the position of the weights, how tight the arm and post were fastened together, the angle of the base, etc. Following Ss exploration with the apparatus they were asked to perform "fair tests" to prove that the independent variables mentioned actually did make a difference in the number of times the arm would spin. Again whenever a test was performed Ss were asked questions such as these: Is this a fair test? Why is it a fair test? Does it prove that it makes a difference? Why else might the arm spin more times? (i.e., were all other independent variables held constant?).

The general intent of this session was similar to that of the second session and the fourth and final session. The concepts underlying the questions and materials were identical in all sessions. The symbolic notation (the language used) remained invariant, while transformations in imagery were gained by using materials extending from the familiar to the unfamiliar. Ss were given a variety of concrete experiences so they could learn by doing and at each opportunity they were challenged to transform that doing into language.

Session 4. In this session the use of concrete materials as the source of activity and discussion was replaced by the use of written problems. Problems posed only in a written fashion were considered to represent an additional step away from the concrete and towards the abstract or formal level. Probing questions relative to Ss understanding of the written situations were asked as was done in the previous sessions. In a sense learning by doing was replaced by learning by discussion (language alone). The following two written problems were presented and discussed at length.

Written problem 1.

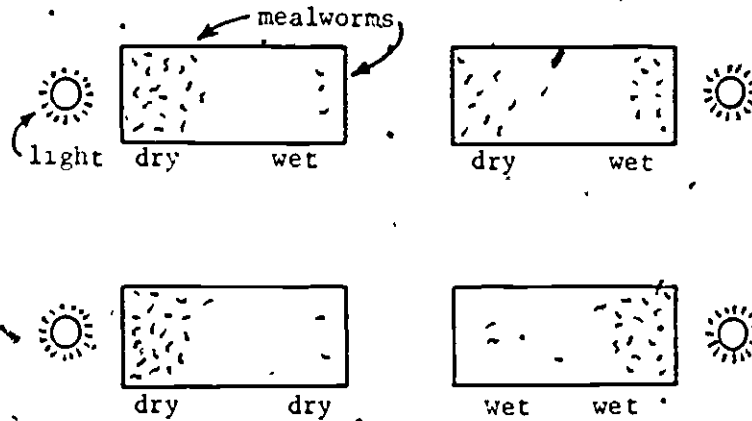
Fifty pieces of various parts of plants were placed in each of five sealed jars of equal size under different conditions of color of light and temperature. At the start of the experiment each jar contained 250 units of carbon dioxide. The amount of carbon dioxide in each jar at the end of the experiment is shown in the table.

Which two jars would you select to make a fair comparison to find out if temperature makes a difference in the amount of carbon dioxide used?

Jar	Plant Type	Plant Part	Color of Light	Temp. (°C)	CO ₂
1.	Willow	Leaf	Blue	10	200
2.	Maple	Leaf	Purple	23	50
3.	Willow	Root	Red	18	300
4.	Maple	Stem	Red	23	400
5.	Willow	Leaf	Blue	23	150

Written problem 2.

An experimenter wanted to test the response of mealworms to light and moisture. To do this he set up four boxes as shown in the diagram below. He used lamps for light sources and watered pieces of paper in the boxes for moisture. In the center of each box he placed 20 mealworms. One day later he returned to count the number of mealworms that had crawled to the different ends of the boxes.



The diagrams show that mealworms respond (respond means move to or away from) to:

- A. light but not moisture
- B. moisture but not light
- C. both light and moisture
- D. neither light nor moisture

Posttests

The following tasks were individually administered to Ss in phase one of the posttesting.

Bending rods. This task tested S's ability to identify and control variables. Given six flexible metal rods of varying length, diameter, shape, and materials which were fastened to a stationary block of wood, S was asked to identify variables and demonstrate proof of the affect of each variable on the amount of bending of the rods.

The pendulum. The pendulum task tested Ss' ability to control and exclude irrelevant variables using a simple pendulum. First E pointed out the independent and dependent variables. S was then given the problem of determining what variables affect the period. Since the only causal variable was length of the string, the variables of bob, angle of drop, and force or push must be excluded. This demonstration required understanding of concept "all other things being equal"--the trained concept.

The balance beam.⁴ Using a balance beam and hanging weights, this task tested S's ability to balance various combinations of weights at various locations along the beam, e.g., given a 10 unit weight 5 units of length from the fulcrum, S was asked to predict the proper location of a 5 unit weight to achieve a balance. Successful completion of this task implied understanding of inverse proportionality.

Piagetian level of performance on these three tasks was assessed on the basis of the quality of S's verbal responses and their ability to exhibit the appropriate behavior. Performances were categorized into the following levels.*

Piagetian Level	Points
Preoperational	1
Early concrete operational-IIA	2
Middle concrete operational	3
Fully concrete operational-IIB	4
Post-concrete operational	5
Early formal operational-IIIA	6
Middle formal operational	7
Fully formal operational-IIIB	8

The Peel question.¹⁸ A paragraph and question written by Peel which involved the floods of Florence, Italy was modified to read as follows:

All countries have art museums and Mexico is very rich in art treasures. Many people travel to Mexico just to see these old paintings and statues. Floods in Mexico recently damaged many of these great works of art. Old paintings are rare, valuable and beautiful and should be kept in a safe place.

Question: Are the people of Mexico to blame for the damage to the paintings and art treasures?

Responses were tape recorded and classified into one of the following categories:

1. Restricted--one point.
Irrelevancy, tautology and inconsistency may dominate. S may deny premises or other conditions of the problem.
2. Circumstantial--two points.
Thinking is dominated by the content of the material. S is unable to look outside it.
3. Imaginative--three points.
The subject realizes that he has to go beyond the content of the passage to evoke possible hypothesis from his own experience--extenuating possibilities are evoked.

*For a more detailed explanation of the scoring procedures used for this task as well as for the pendulum and the balance beam tasks see Lawson, Nordland, and DeVito:²⁸

The following measures were administered as group tests during the second phase of the posttesting.

The spheres task.¹¹ The spheres task consisted of three written questions requiring understanding of the necessity for the control of variables in the context of rolling spheres down inclined planes. The independent variables were the position on the inclined plane from which the spheres were released, the weight of the spheres, and the weight of target spheres which were positioned at the base of the inclined plane. The dependent variable was the distance traveled by the target sphere after it was hit by the rolling sphere.

Questions required Ss to select the proper release positions, weight of rolling spheres, and weight of target spheres to determine the affect of each variable on the distance the target sphere would travel. All selections were followed by written explanations. Responses on each of the three questions were classified into the following four categories.

1. Incorrect selection, or a correct selection but irrelevant explanation.--one point.
2. Correct selection followed by a simple description of what would occur when the experiment was performed.--two points.
3. Correct selection followed by an explanation stating that the selection was made to insure that the test be fair.--three points.
4. Correct selection followed by an explanation stating that if the comparison was not made in this fashion then it would not be fair, therefore an unambiguous solution would not be obtained.--four points.

The Longeot examination.^{19, 20} The original Longeot examination, is a subject matter free examination, consisting of 28 problems requiring either concrete, transitional, or formal operational thinking for successful solution. Since the time available did not allow administration of all 28 problems, a shortened version of the examination consisting of eight problems was administered. Two problems involving each of the following reasoning processes were selected: class inclusion operations, proportional reasoning, propositional logic, and combinatorial analysis. The examination required approximately 20 minutes for completion. Total scores were obtained for each S. Also, following procedures adopted by Longeot, Ss were categorized into concrete operational-IIA, concrete operational-IIB, post-concrete operational, formal operational-IIIA, and formal operational-IIIB levels of intellectual development.*

Combinatorial question. One question involving combinatorial analysis was given to the sample of fifth grade Ss. The question read as follows:

The Rapid Rover Bicycle Club has license plates for its members. On each license plate is a combination of letters. How many different license plates can you make up using only three letters A, B, and C, and not using a letter more than once in the same license plate?

One point was awarded for each original license plate S was able to generate.

*Details of the examination and the scoring procedures can be obtained from the authors.

Logic question. The question involving propositional logic which was presented to the fifth grade sample was:

When big dogs bark the mailman runs.
You see the mailman running.
Did a big dog bark?

Subjects were instructed to answer "yes" or "no" and justify their answer. A "yes" answer constitutes committing the logical fallacy known as affirming the consequent. One point was awarded for a correct answer and zero points were awarded for an incorrect answer.

Results

Pretest to Posttest Gains in Intellectual Level

Table 1 shows the mean pretest and posttest levels of intellectual development for both the fifth and seventh grade samples as measured by the bending rods task. The fifth grade experimental group showed a gain in level from 3.93 (slightly less than fully concrete operational-IIB) to 7.06 (between early formal-IIIA and full formal operational-IIIB). The Mann-Whitney μ test²⁹ was used to test for significant differences in pre to posttest performance. The calculated Mann-Whitney μ value of 3.5 for experimental group's gain was highly significant ($p < .001$). The fifth grade control group's slight gain from 4.00 to 4.42 was not significant ($\mu = .92, p > .10$). The seventh grade experimental group showed a gain in level from 4.50 to 7.37. This gain was highly significant ($\mu = 10.5, p < .001$). The seventh grade control group's gain from 4.75 to 5.43 was not significant ($\mu = .94, p > .10$).

TABLE 1
MEAN PRETEST AND POSTTEST LEVELS OF INTELLECTUAL
DEVELOPMENT AS MEASURED BY THE BENDING RODS TASK

Group	Pretest	Posttest
<u>Fifth Grade</u>		
Experimental	3.93	*7.06
Control	4.00	4.42
Mean	3.96	5.75
<u>Seventh Grade</u>		
Experimental	4.50	*7.37
Control	4.75	5.43
Mean	4.62	6.41

* $p < .001$

Experimental and Control Group Posttest Comparison--Fifth Grade

Means and standard deviations for the trained task (bending rods), the specific transfer tasks involving the concept of controlling variables (pendulum task, spheres task), and the nonspecific transfer tasks of general intellectual-level (balance beam task, Peel question, combinatorial question) for the fifth grade experimental and control groups are shown in Table 2. The Mann-Whitney U test was used to test for significant differences in the experimental and control group performance. The table values show that the experimental group performed significantly better than the control group on the bending rods task ($p < .001$), on the pendulum task ($p < .10$), and on the spheres task ($p < .10$). However, on the remaining measures, group differences did not reach significance ($p > .10$).

TABLE 2
MEANS, STANDARD DEVIATIONS AND MANN-WHITNEY U VALUES.
FOR EXPERIMENTAL AND CONTROL GROUP POSTTEST MEASURES--
FIFTH GRADE SAMPLE

Posttest Measure	Experimental		Control		
	M	SD	M	SD	
<u>Trained Task</u>					
Bending Rods	7.06	.99	4.43	1.02	**10.5
<u>Specific Transfer Tasks</u>					
Pendulum	5.38	2.13	4.14	.95	*83.5
Spheres	4.75	2.77	3.00	1.18	*78
<u>Nonspecific Transfer Tasks</u>					
Balance Beam	4.63	1.15	4.14	.54	89
Peel	2.00	.37	2.00	.39	105.5
Combinatorial	5.74	.45	5.29	1.07	88

* $p < .10$; ** $p < .001$.

Experimental and Control Group Posttest Comparison--Seventh Grade

Means and standard deviations for the six posttest measures for the seventh grade experimental and control groups are shown in Table 3. Inspection of the table shows that the experimental group performed significantly better than the control group on the bending rods task ($p < .001$) and on the specific transfer tasks--the pendulum task ($p < .001$) and the spheres task ($p < .01$). The experimental group also performed significantly better on one measure of nonspecific transfer--the Longest examination ($p < .05$). However, on the balance beam task and on the Peel question group differences failed to reach significance ($p > .10$).

TABLE 3
 MEANS, STANDARD DEVIATIONS AND MANN-WHITNEY U VALUES
 FOR EXPERIMENTAL AND CONTROL GROUP POSTTEST MEASURES--
 SEVENTH GRADE SAMPLE

Posttest Measure	Experimental		Control		U
	M	SD	M	SD	
<u>Trained Task</u>					
Bending Rods	7.37	.81	5.43	1.50	***24
<u>Specific Transfer Tasks</u>					
Pendulum	7.56	.73	5.13	1.54	***20
Spheres	6.88	2.78	3.94	2.02	**53
<u>Nonspecific Transfer Tasks</u>					
Balance Beam	4.63	1.15	4.63	.96	121
Peel	2.31	.60	2.38	.72	181
Longeot	4.13	1.45	3.44	1.36	*69

* $p < .05$; ** $p < .01$; *** $p < .001$.

Comparison of Pretest Level of Intellectual Development and Posttest Performance--Combined Experimental Groups

Table 4 shows a comparison of Ss' level of intellectual development as determined by performance on three pretest tasks with their performance on the posttest measures. The 32 experimental group Ss from the fifth and seventh grade samples were judged to be at either the concrete-IIA, concrete-IIB, post-concrete, or formal-IIIA level of intellectual development on the basis of combined responses on the conservation of weight, conservation of volume, and volume displacement tasks. The number of Ss which were categorized into each level is shown in the table as is the mean posttest score for each group on each posttest measure. F-ratios and their associated probability values are also shown. For the trained task (bending rods) the more formal subjects (post-concrete and formal-IIIA) demonstrated slightly higher posttest scores (6.85 for the concrete-IIA Ss to 7.60 for the formal-IIIA Ss). The group differences, however, were not significant ($F_{3,28} = .92$, $p = .45$). Mean scores for the specific transfer tasks (pendulum and spheres) were also slightly higher for the more formal Ss. The obtained F-ratios and probability levels for the mean differences for the pendulum and spheres tasks were $F_{3,28} = 2.59$; $p = .07$ and $F_{3,28} = 2.69$; $p = .06$ respectively. Significant group differences were found on the Longeot examination ($F_{3,12} = 3.79$; $p < .05$) but not on the balance beam task and Peel question ($p > .10$ for both measures).

TABLE 4

COMPARISON OF PRETEST LEVEL OF INTELLECTUAL DEVELOPMENT
WITH MEAN SCORES ON POSTTEST MEASURES FOR COMBINED
FIFTH AND SEVENTH GRADE EXPERIMENTAL GROUPS

Posttest Measure	Pretest Level of Intellectual Development				F-ratio	Prob.
	Concrete-IIA (n = 7)	Concrete-IIB (n = 11)	Post-concrete (n = 9)	Formal-IIIA (n = 5)		
<u>Trained Task</u>						
Bending Rods	6.85	7.09	7.44	7.60	.92	.45
<u>Specific Transfer</u>						
Pendulum	5.00	6.72	6.55	7.80	2.59	.07
Spheres	4.00	5.27	6.56	8.20	2.69	.06
<u>Nonspecific Transfer</u>						
Balance Beam	4.00	4.54	5.11	4.80	1.38	.27
Peel	2.14	2.18	2.00	2.40	.64	.60
Longeot	2.00 *(n = 2)	3.83 (n = 6)	4.33 (n = 3)	5.20	3.79	.04

*Since the Longeot examination was not administered to both samples, the number of subjects in the first three levels was reduced.

Discussion

The answer to the first question posed at the outset of this investigation is yes. Instruction incorporating the described procedures can affect the transition from concrete to formal cognitive functioning in these fifth and seventh grade students with respect to the ability to control variables. The results in Table 1 indicated both fifth and seventh grade experimental group Ss performed at the formal level on the posttests. Not surprisingly the seventh grade Ss performed at a slightly more formal level than the fifth grade Ss. The finding that the experimental groups also performed significantly better than control groups on the specific transfer tasks (the pendulum task and the spheres tasks) indicates that the training was generalizable to tasks involving novel materials (see Tables 2 and 3). The answer to the second question therefore is also yes.

On tasks designed to measure nonspecific transfer of training (i.e., tasks involving concepts other than the trained concept but still involving concrete and formal reasoning) differences between the fifth grade experimental and control groups were not significant ($p > .10$). This indicates that, although the training was effective in promoting formal thought with regard to one aspect of formal reasoning, it was limited in extent. This is precisely the result predicted by Ausubel.¹² In an extensive review of studies attempting to train conservation reasoning Brainerd and Allen¹³ found a similar result. They reported that "In short, those studies that looked for specific transfer of induced first-order conservations, without exception, have found it." (p.137). Conversely, in several studies which looked for nonspecific transfer of induced conservation, none was found. These results were taken to be supportive of Piaget's position with regard to the existence of general levels of development. In light of these findings, the fact that the seventh grade experimental group performed at a significantly ($p > .05$) more formal level on one measure of nonspecific transfer (the Longeot examination) seems indeed surprising. Did the training facilitate a general shift in the experimental group's ability to reason formally? At first glance it appears that this may be the case since the Longeot examination has been shown to be a valid measure of concrete and formal reasoning abilities.^{21, 22} An alternative explanation however, can be advanced. That is, the difference is not due to the fact that the experimental group performed more formally because of a general advance in reasoning but that the control group performed below their capabilities. Possibly a personal rapport established during the training sessions among the examiners and the experimental subjects did not develop with the control group subjects. For this reason the control group simply did not try as hard as the experimental group did on the written examination. The likelihood of this occurring on the Longeot examination was great because it, unlike the interview tasks, did not involve personal contact with the examiners. Which of these interpretations is correct we cannot say. Indeed other factors may be operating. However, on the average the control group did perform at a somewhat more concrete level on the Longeot examination than they did on the bending rods, pendulum, and balance beam tasks.

Data on Table 4 can be used to answer the fourth question addressed by this investigation. What is the relationship between a student's level of intellectual development and his ability to profit from the training? The data indicate that the more formal subjects (those in the post-concrete and formal-IIIA levels) were somewhat more receptive to training than the

more concrete subjects (those in the concrete-11A and concrete-11B levels). Nevertheless the concrete-11A and concrete-11B subjects did perform at the formal level on the bending rods posttest task (recall a score of 6 was equivalent to the formal-11IA level and a score of 8 was equivalent to the formal-11IB level). This finding is somewhat contrary to the Piagetian position that training can be effective only for persons in a transition period. The fact that specific transfer of training (a better indication of actual comprehension of the trained concept) was significantly related ($p < .10$) to pretest level of intellectual development is a result more closely aligned with the Piagetian position.

What then can be said about the transition from concrete to formal operational thought in light of these experimental results and our conversations with children? It appears to us that formal operations develop initially as intuitions during the concrete stage, perhaps as early as six to seven years of age. At the onset of this investigation virtually all the experimental subjects insisted that to determine which tennis ball was the bouncier the balls must be dropped from the same height and hit the same surface on the floor. In each instance Ss demonstrated an intuitive feeling that the tests were "not fair" and would respond by saying: drop them from the same height, make them both hit the floor, don't spin one, etc. After the comparisons with the tennis balls were made they were able to accept or reject them as fair or unfair but they were unable to state a general rule or procedure for performing fair tests prior to the test itself (i.e., to perform a fair test keep all the factors equal except that which you are testing). Not even the most articulate S's were able to spontaneously respond by telling E to have "every thing the same" for both balls. Even when they were asked to summarize their instructions without mentioning specific factors they were initially at a loss for words. Apparently they had a feeling for evenness, fairness, and symmetry but not a general rule to act as a guide for behavior--i.e., they lacked the ability to use language to structure their thinking. This phenomenon appears very much akin to the experience we all have had when we "know" something is true but just cannot seem to find the words to explain it. Our belief is that the extension of this intuitive understanding to the point where this intuition can be expressed clearly through the use of language and applied successfully to solve problems constitutes the acquisition of formal thought. This process which enables persons to overcome the pull of the perceptual field (they are no longer "object bound") we believe is the fundamental process in intellectual growth. For intuitions to manifest themselves in the form of useful linguistic rules (formal operations) we presumed (and the experimental results supported) that children need (1) a variety of concrete experiences involving a conceptualization and instrumental activities and (2) a useful symbolic notation which remains invariant across transformations in images--in this instance the symbolic notation was language, the key words being "fair test" and "unfair test". This, of course, is essentially the position taken by Bruner and Kenney¹³ cited above. It incorporates key points suggested by Raven¹⁰ as well. Raven, in designing instructional strategy to facilitate the acquisition of logical operations suggests three necessary factors: (1) the task organization must correspond to the child's levels of reasoning, (2) the instructional strategy must incorporate the active engagement of the student in using his logical operations in the construction of rules and concepts, and (3) concrete referents must, whenever possible, be provided.

The position taken by Elkind³¹ that instruction in controlled experimentation should generally not be introduced until adolescence seems unfortunate. Rather what seems called for is a very gradual introduction and continued reintroduction of lessons involving concrete materials and activities which enable students to make comparisons and to make judgments on the basis of their comparisons. The elementary school science program recently developed by the Science Curriculum Improvement Study (SCIS) at the University of California, Berkeley appears to do just this. SCIS first graders begin to carry out experiments on living organisms and physical materials. At first these experiments are conducted with much teacher guidance. However, as the students continue to perform experiments they gain experience and are gradually able to design and conduct these experiments on their own. The SCIS first grade students, (with much guidance from the teacher and much peer interaction) can carry out and discuss scientific experiments based on their intuitive feel for evenness and fairness. It is likely that only through a rich variety of such experiences which progress from the intuitive to the abstract, will these intuitive feelings become explicit and powerful conceptualizations during adolescence.

What then about the formal operational stage in general? Does it exist? To that question we have no clear answer. However, a number of studies have shown that the development of formal ideas such as proportional reasoning and the control of variables do develop roughly in a parallel fashion.^{22, 32, 33} For example Lawson³² found correlations of .40 to .48 ($p < .01$) between the bending rods at the balance beam tasks in samples of high school biology, chemistry and physics students. Further the mean level of performance on the two tasks was about identical for the three samples. In other words, if a student performs at a formal-IIIA level on the bending rods task it is likely (but by no means certain) that he will also perform at the formal-IIIA level on the balance beam task. The correlation between the same two tasks in the sample of fifth and seventh grade subjects in this study following training was predictively less ($r = .53$ and $.23$ respectively). The training, in effect, increased the decalage (separation) between these two aspects of formal reasoning.

The posttest performance of one student on the bending rods task was particularly interesting and demonstrative of this artificial separation. He performed almost perfectly. He systematically and unhesitatingly isolated and proved the effect of each variable until he attempted to prove that the shape of the rod made a difference in the amount it would bend. He chose two rods of different shape but of equal thickness, equal length, same material and hung the same amount of weight on each rod. Then he checked to see which rod was bending more and could not notice a difference. What was extraordinary was that he had only extended the rods from the block of wood in which they were fastened about 3 cm. When no difference in bending was observed he was unable to proceed. This a phenomenon that we have never observed in non-trained subjects who spontaneously and unhesitatingly controlled variables (i.e., a spontaneous formal-IIIB performance). When differences in bending are likely to be small these subjects will spontaneously pull the rods out as far as possible in order to magnify any differences which may exist. The difference in bending between the square and the round rods varies directly with the length of the two rods. Understanding of this proportional relationship was lacking in this trained subject and other trained subjects as evidenced by their lower performance on the balance beam task. Therefore it appears that the training manifested itself in one aspect

of formal thought but not in what could be interpreted as formal reasoning in general. Kohlberg and DeVries³³ claim such a concept as formal reasoning in general is meaningful because they and others have isolated a general Piagetian cognitive-level factor distinct from psychometric intelligence.* One might ask then was the training of any value to the students? The answer we believe is yes. It does represent a meaningful but limited advance toward an abstract quality of thought in the student. Inhelder and Matalon³⁵ apparently would agree. In a discussion of the acquisition of trained conservation concepts they stated, "This process of acquisition which can, of course be accelerated by training, corresponds to a general progress toward an 'operational' quality in the thought of the child." (p.446)

It should, however, be pointed out that the aim of efforts such as those reported in this study if used on a wide scale in classroom should not be to accelerate intellectual development as mentioned by Inhelder and Matalon but to avoid what might be called "stage-retardation." Ample evidence exists, as mentioned previously, that this phenomenon of stage-retardation is indeed widespread.

*The unity of formal thought has been brought into serious question by a number of Piageton scholars. Perhaps the most notable is Professor Eric Lunzer. In his 1973 address to the Jean Piaget Society³⁴ he reviewed some of the pertinent literature and recent findings relevant to this issue. Piaget himself has modified his earlier position somewhat in light of recent findings.

Synopsis

An attempt to train concrete operational fifth grade students and an attempt to train concrete operational seventh grade students to perform at the formal operational level on tasks demanding the control of variables are reported. The training was conducted in four individual sessions of approximately 30 minutes each. The training sessions were designed to represent a synthesis of ideas concerning the mechanisms of development put forth by Piaget, Ausubel, Bruner, and C. Lawson. The training was successful ($p < .001$) and specific transfer of the trained concept was obtained for both samples. Pretest level of intellectual development was significantly related to success on posttest tasks of specific transfer ($p < .10$). On one post-test task designed to measure nonspecific transfer the trained seventh grade subjects scored significantly higher ($p < .05$) than the control subjects. The effectiveness of the training suggests that properly designed instruction, which is based on students' intuitive conceptual understanding at the concrete level, can raise this intuitive understanding to the level of a meaningful verbal rule which then can be successfully applied in a variety of problem situations.

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