DOCUMENT RESUME

ED 063 896	24	HE 003 215

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TITLE	Logical Thinking in College Freshmen. Final Report.
INSTITUTION	Rutgers, The State Univ., New Brunswick, N.J. Graduate School of Education.
SPONS AGENCY	Office of Education (DHEW), Washington, D.C. Bureau of Research.
BUREAU NO	BR-0-B-105
PUB DATE	Apr 72
GRANT	OEG-2-7-00039(509)
NOTE	42p.
EDRS PRICE	MF-$0.65 HC-$3.29
DESCRIPTORS	*Abstract Reasoning; *Academic Performance; *College Freshmen; *Higher Education; Logical Thinking

ABSTRACT

This study was designed to serve several purposes: (1) to determine the level of logical thinking in first term college freshmen of both sexes; (2) to find if their level rose during the first year and especially if it increased as a result of brief intervention aimed at raising the level; and (3) to examine the relationship between logical thinking and selected academic performance variables. A random sample of 60 men and women was selected from among the freshmen of 2 undergraduate colleges at Rutgers University. Results of the study show that the insufficiently developed level of logical thinking of regularly admitted college freshmen puts them at a disadvantage to benefit optimally from higher education and to cope with life problems that require such thinking. The experience of the college freshman year does not have a material effect in raising the level of thinking. The brief intervention on a small sample did yield significant results that warrant further study, especially with longer-term intervention. (Author/HS)

BR O-B-105

FINAL REPORT
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Acknowledgments

To Suzanne Martorano who served as research assistant. To the following for advice in connection with one or more aspects of the study or this report: Hermina Sinclair (Geneva), Howard Gruber, Carol Keasey, Edith Neimark, Pietro Pascale, Eleanor Ross, and Jane Raph (Rutgers), Andrew Schwebel (Ohio State), Robert Schwebel (Berkeley). To Marion Keller for administrative assistance and typing of the report. To the college freshmen who served as subjects. To the Rutgers University Research Council for a preliminary grant for this study.

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Summary

The study was designed to serve several purposes: to determine the level of logical thinking in first term college freshmen of both sexes; to find if their level rose during the first year and especially if it increased as a result of brief intervention aimed at raising the level. Still another purpose was to examine the relationship between logical thinking and selected academic performance variables.

A random sample of 60 men and women was selected from among the freshmen of two undergraduate colleges at Rutgers University, Douglass and Rutgers. This sample was used to obtain normative data on logical thinking, to test for change during the freshman year and to relate logical thinking to other variables. A further sample of 15 volunteer freshmen was used. These were specially admitted students who did not meet the standard admissions requirements. They were combined with the random sample of 60. The bottom third of the distribution of the combined sample on the first administration of the problems was used for intervention purposes.

Five apparatus-type problems requiring logical thinking for their solution were selected. Rods, Balance Scale, Truck were used in the first administration (first term), and Rods (repeated), Chemical Combinations, and Shadows, in the second administration (second term). Three scorers independently scored the responses of a 15% sample on the three problems in the first administration and the ensuing interscorer reliabilities were .93, .93, and .92.

Intervention took the form of two 1½ hour sessions a week apart, with groups of 2 or 3 students. It was conducted with an awareness of the subject as a person (affective and cognitive indivisible), and with the aim to activate the person to seek problem solutions and to relate these actions to the problems of college work and life.

A scale of 1 to 4 was used to score the problems: 1 is lower level concrete operations, 2 is upper level concrete, 3 is lower level formal operations, and 4 is upper level formal operations. (Lower level formal

thought appears at age 11 and afterward.) In the first administration the mean of the three problems for men was 3.23, for women, 2.81. The difference is significant at the .01 level. Thirty percent of the women scored at the upper concrete level but only 3.5% of the men, while 10% of the women and 28.5% of the men scored at the upper formal level.

The number of science courses taken in high school was not significantly related either to performance on the logical problems or to high school or college achievement or to SAT scores. Second term freshman grade point average was significantly related to the mean of the logical problem scores for men but not for women.

When the mean of the first and second administration problem scores for men and women were compared, no significant differences were found; that is, no significant increase in ability on these problems occurred during the course of the freshman year for this random sample of freshmen.

When the experimental and control subsamples (who together represented the lower third of the combined random and volunteer samples) were compared, no significant difference was found between them either on the mean of the first or the second administration scores.

However, when the gain between the first and second administration scores was compared, the results were different: The control group showed a non-significant gain whereas the experimental (intervention) group showed a significant gain at the .01 level.

The insufficiently developed level of logical thinking of regularly admitted college freshmen puts them at a disadvantage to benefit optimally from higher education and to cope with those of life's problems that require such thinking. The experience of the college freshman year does not have a material effect in raising the level of thinking. The brief intervention on a small sample did yield significant results that warrant further study especially with longer-term intervention. It also justifies that closer attention be given to the facilitation of logical thinking in planning both the process and content of educational experience at the college level.

Logical Thinking in College Freshmen

Introduction

The loosening up of traditional admissions requirements in the 1960's gave rise to a variety of supportive and compensatory services for students inadequately prepared for college. During the post World War II period similar services were set up for veterans who had not planned to enroll in college and needed help when they got there. During both periods a fundamental cognitive ability has been ignored as a subject demanding attention, i.e., the level of logical thinking of the college freshman. For it is possible that some failures among those students but also among those who meet the established admissions requirements are caused by the inadequacy of their cognitive structures, in particular by their not having attained, or attained sufficiently, the level of formal operations, to use the terminology of Inhelder and Piaget (1958). To the extent that the development of formal operations can be facilitated in college freshmen, the typical compensatory or remedial program is not designed for that purpose.

If college freshmen are indeed insufficiently developed in their thinking processes, it remains to be seen whether intervention designed to facilitate the completion of the cognitive developmental process can succeed in enabling them to cope with the intellectual demands of higher education.

Three assumptions underly the rationale for this study:

1. Higher education requires the kind of logical processes, problem solving ability, strategies of classifying, ordering, correlating, hypothesizing and testing out, that are represented by the concept of formal operations in the Piagetian system of cognitive development.

2. In the absence of sufficient development of these abilities, no amount of content-oriented tutoring or other remedial education suffices to enable a student to profit materially from higher education.

3. Educational experiences can be devised to inculcate these abilities even as late as the college freshman year.

The objectives of the study are to determine:

1. the level of logical thinking in a random sample of college freshmen of both sexes;

2. relation among variables: level of logical thinking, number of high school science courses, high school rank, SAT scores, college grade point average;

3. changes in the level of logical thinking, if any, during the first year of college;

4. the affects of instruction designed to stimulate the development of formal operations in a small sample of those who scored in the lowest one-third of combined random and volunteer samples on logical thinking.

Inhelder and Piaget (1958) said: "It is surprising that in spite of the large number of excellent works which have been published on the affective and social life of the adolescent. . . . so little work has appeared on the adolescent's thinking." (p. 334) The situation has not changed substantially and there is still a paucity of studies about those years and especially about intervention for the purpose of facilitating intellectual development.

Some success has been achieved at younger ages. Olton and Crutchfield (1969) were successful in teaching "productive thinking skills" to fifth and sixth grade students over an eight week period, and the gains were maintained six months later.

Some studies give reason to believe that the developmental process is still active during the college age years and give at least oblique support to the notion that <u>cognitive</u> development is still underway. Kohlberg (1968) said that while individuals may be fixated in their development of moral judgment at any one of six stages, the process is still underway during late adolescence.

Perry (1968) identified nine stages or "positions" in intellectual and ethical development growing out of his longitudinal study of Harvard students. He found college students at all of these positions and observed change during the course of their four years of college in the direction of a "higher" development, that is, in the direction of relativism and commitment versus absolutism.

Elkind reported several normative investigations that are suggestive of the developmental process. In a study (1966) using 32 children in fourth grade and 32 in seventh and eighth the results showed the adolescents much more successful than the younger children in shifting their orientation when faced with a concept-formation task. The mental processes of the adolescents were more mobile and flexible in problem solving. These are qualities that were developed in Olton and Crutchfield's experimental subjects when the independent variable was an instructional program.

Elkind (1962) reported a study on quantity conceptions in college students. Previously he had found abstract conception of mass attained by age 7 and that of weight by 9 (in both instances, that is, 75% of the subjects had been successful). These results were consistent with Piaget's. But whereas Piaget's 11-12 year olds had mastered the concept of volume, only 27% of Elkind's had. By ages 12-18 Elkind found that 87% had mass and weight conception but only 47% had volume, with a regular increase from 12 to 18 and with boys showing more frequent attainment of volume at all ages, compared with girls. In his study of the college students (n of 240) 92% had conceptions of mass and weight. Surprisingly 8% of students in two 4 year colleges in the Boston area did not. Furthermore, only 58% had conservation of volume, and the errors of the 42% were the same as those made by children though put in more sophisticated language. The sex differential was large (75% success for the males and 52% for the females). For both sexes there was an increase with age in high school but only for the females in college.

Elkind posits a social role hypothesis: the female college population is more heterogeneous because many

women attend for social opportunity. Those lacking the interests and concepts drop out. Another possible hypothesis is that those who need the concept of volume (male and female) develop it in college and that some college programs, especially those that attract more women, do not require it for successful completion. Still another hypothesis is that instructors have stereotypic sex role attitudes and expect and encourage sex differences.

Lovell (1971) distinguishes between concrete and formal thought in terms of the levels of relations that are structured. Concrete thought involves first order relations, i.e., as a result of action upon objects relations are structured among the objects. Formal thought, by contrast, means structuring relations between relations. Lovell and Butterworth (1966), employing some of the same problems of proportionality used in this study, found that even at age 15 only 45 to 50 percent of the responses involving relations between relations were correct.

Lovell's (1971) report on formal thought in history suggests it is appropriate to evaluate the level of logical thought in college age individuals. Formal thought in history comes late so that "a mental age of 16 to 16½ years seems to be necessary."

While much of the prior literature is only exploratory, it does offer fruitful leads. Many at the college age have not advanced to the highest level of formal operations and some may not have established themselves beyond the concrete operational stage. Also, development probably continues during the college years, possibly at different rates for different operations for the two sexes. Studies at earlier ages give reason to test the hypothesis that intervention in the form of facilitating experience can foster the development of abstract problem solving. Langer (1969) reporting on exploratory studies states the view that a child will tend to change when disequilibrated; that is, when he experiences contradictions in his logical construction of the world. The disequilibrium of inadequately prepared college freshmen may provide the energy and support for some kind of instructional program. Unlike social and physical knowledge, however, logico-mathematical can not be taught directly, and the intervention presumably requires the kind of active experience that fosters the development of formal operations.

Procedures

Subjects. The subjects were freshmen at Rutgers University in 1970-71. They were selected from two sources, from the regularly admitted students who were randomly selected for the study; from the specially admitted students who volunteered for the study. Sixty were selected randomly from the file of freshmen at Douglass and Rutgers Colleges, two residential colleges of the University in New Brunswick, New Jersey, the first for women, the second for men. Thirty were selected from each. There were 58 usable protocols from the first administration of the problems and 55 from the second.

Fifteen subjects came from the 70 freshmen enrolled in the Urban University Department in the New Brunswick area. This program was open to high school graduates, regardless of diploma, whose credentials were below the level required on the basis of the established criteria for admissions and whose family also met certain negative income criteria. All of the freshmen students in the UUD were invited to participate as subjects through announcements in class. Fifteen students (8 female, 7 male) took the pre-administration, and nine students appeared for both the first and second administrations, two males and seven females.

The intervention subsample consisted of the bottom third distribution of scores on the first administration of the total sample, i.e., of the 60 randomly selected and the 15 specially admitted students. The subsample of 25 was reduced to 17 as a result either of drop-out from college or non-appearance for intervention. Ten of the 17 were in the experimental and 7 in the control group.

Each student was paid $2 per evaluation session which lasted an average of 50 minutes.

The following was obtained for each of the students: birth date, chronological age, high school rank, SAT scores (verbal and mathematics), number of

science courses in high school, first year college grade point average (end of year).

Problems. Five problems requiring hypothetico-deductive reasoning were selected. To minimize the possible effects of familiarity with problems only one (Rods) was repeated in the second administration.

A one way vision screen was used to train the project assistant (a white female doctoral student in developmental psychology) to administer the problem. Tape recordings were used to establish a standard frame of reference in using the clinical interview (as opposed to a rigid interview schedule). Objectives in the administration of the problems were to create the best possible climate for problem solution and to encourage free use of the apparatus to test hypotheses.

The examiner introduced the subject to the project by conveying the following. "We are studying problem-solving in college freshmen. People deal with different kinds of problems in different ways and we're trying to learn more about it. We hope as a result to be able to help college students. Thanks for helping us."

Following is a description of the apparatus and the tasks for each problem.

Rods Problem. The apparatus consists of 6 rods representing three variables: length (1' and 2'), diameter (1/8" and 3/16") and type of material (brass, steel and wood); a vise to hold the rods, and weights (1, 3 and 4 ounces) to attach to the notched tip of the rods. The task is to establish the relationship of these variables to flexibility. Deduction is necessary because of the combination of variables in the rods.

The examiner said, "This problem is about the flexibility of these rods. . . . Your first problem is to find out which bends most and least. . . ." She used some typical questions in this and the other problems, such as: How do you explain it? How did you discover that? How can you prove it (or test it out)?

For more details on the administration of this and the other problems, see Appendix 1.

The Balance Scale Problem. The scale, made of plexiglass, consists of an ½" base, a 12½" post and a 14" crossbar with holes at 13 equally-spaced (9/16") points on each side of the fulcrum for weights (1/4, 1/2, 3/4 and 1 ounce lead weights) to be hung. The task is to obtain balance by using unequal weights at points of unequal distance from the center, and to demonstrate an awareness of the law of proportionality wherein weight and distance compensate for each other to achieve symmetry.

The Truck Problem. Constructed of plexiglass, the equipment consists of a tower 21" high and a road 19" x 2" whose height (inclination) can be altered at will by the subject. A toy truck, set on the plane, and suspended by a cable, is raised or lowered on the plane by adding or removing weights from a bucket at the other end of the cable. The task is to predict the equilibrium position or the movements of the truck as a function of the three variables (height, weight and counterweight).

The Chemical Combination Problem. Inhelder and Piaget (195[illegible]) describe this task as follows. The subject is given "four similar flasks containing colorless, odorless liquids which are perceptually identical. We number them: (1) diluted phosphorus acid; (2) water; (3) hydrogen peroxide; (4) thiosulphate; we add a bottle (with a dropper) which we will call g; it contains potassium iodide. It is known that oxygenated water oxidizes potassium iodide in an acid medium. This mixture (1 + 3 + g) will yield a yellow color. The water (2) is neutral, so that adding it will not change the color, whereas the thiosulphate (4) will bleach the mixture (1 + 3 + g). The experimenter presents to the subject two glasses, one containing 1 + 3, the other containing 2. In front of the subject, he pours several drops of g in each of the two glasses and notes the different reactions. Then the subject is asked simply to reproduce the color yellow, using flasks 1, 2, 3, 4, and g as he wishes." (p. 109)

This problem like that of the Rods requires systematic manipulation of variables. But where the Rods requires the comparison of each variable

with each of all the others, this one does not, so that a subject could by chance find the correct color combination without systematically excluding the remaining possibilities. However, this task obviously does require the combination of variables.

The Shadows Problem. The equipment consists of a wooden baseboard 35" x 5" with holes 1 inch apart from one end to the other. Attached to one end is a fixed screen. Available with a wooden stem to insert in the holes in the baseboard are four rings in varying diameters (4 5/8", 2", 1 1/4", 3/4") and an electric light (bulb in socket). The subject is asked to use two of these unequalized rings and the light in such a way as to produce two shadows of the same size, i.e., two shadows covering each other; and then to explain why two rings of unequal size produce two shadows of the same size. The task requires the subject to take into consideration the distance between light source (not the screen) and the first ring, then between the two rings. To test comprehension of the principle the subject is asked to predict the correct placement of these rings in different holes (hence different distance from light source and screen) or different rings in the same or different holes.

In summary the problems used in the first administration were: Rods, Balance Scale, Truck. Those used in the second administration were: Rods, Chemical Combinations, Shadows. In the intervention phase, following the first administration, sometimes the Balance and the Truck problems were used as well as several verbal problems or puzzles. See Appendix 3 for these materials.

Scoring. The scoring criteria were taken from Inhelder and Piaget (1958) (see Appendix 2). Scoring was done by the examiner. To evaluate the interrater reliability of the scoring, a subsample of 11 subjects was randomly selected from the first administration representing 15% of subjects in the first administration of the problems. Cassette recordings and observational notations of the examiner were used by the examiner, the investigator and a third psychologist to assign a score independently to each of the 11 subjects on each of the 3 problems in the first administration (Rods, Balance, Truck).

The interscorer reliabilities, using analysis of variance (Winer, 1962) are as follows: Rods, .93; Balance, .93; Trucks, .92. In 19 of the 33 ratings the three scorers agreed; in 14, 2 agreed and the third gave a score one step removed. In no case was there a two or three step difference.

Intervention

During the summer of 1970, following a pilot study in which the tasks were administered to members of the 1969 freshman class the investigator tried out a variety of methods of influencing the level of thinking of college freshmen. Discussions were held with Sinclair (in press) about the Genevan experiment on intervention with children, and with Keasey (1972) about her intervention study with girls, college women, and 50 year old women. The final plans were made in January 1971 after further experimentation with intervention with individuals and small groups using different mixes of affective-didactic components.

The underlying theory is Piaget's on equilibration, the internal self-regulating factor in the individual that coordinates such forces as the physiological, the social and the physical. Developmental advances occur as the individual compensates for disturbances of equilibrium. Presumably when the adolescent or young adult becomes aware of a contradiction, the ensuing state of disequilibrium stimulates the development of more functional operational structures. Furth (1969) writing about the states of intellectual development says they "represent a constant progression from a less to a more concrete equilibrium . . ." (p. 33) College freshmen at the bottom third of the distribution in abstract thinking could well be in a state of disequilibrium.

The following principles were established to guide the experimenter during intervention.

1. Contend with anxiety of subjects. Anxiety was expected because of the acquired reaction to a test-like situation, because of the ambiguity of the intervention experience itself and because of the age and status differential between subjects and the investigator; anxiety in relation to him in a one to one relationship was expected to be higher than in a small group situation; however, that situation was expected to give rise to competitive anxiety or to some form of withdrawal.

2. Conduct the sessions in such a way as to activate the subjects to seek problem solutions, by engaging themselves with the equipment or materials or issues.

3. Bridge the separation between the affective and cognitive, using materials and situations of interest to college freshmen and interpreting the experiment's relevance to their lives; using humor and emotions as freely as they occur but always with focus on the intellectual process (which is not thereby in an emotional vacuum) of enabling the subjects to move to a higher level of thinking.

4. Discuss with them the new understandings and their meaning to their college work and their life. For example, when they work out a solution to the school cafeteria problem they are asked to explain the process and then are involved in a discussion of its application to their studies and/or life's problems.

Early in the design process consideration was given to simple, easily-defined and easily replicated forms of intervention. For elegance of design and ease of administration such forms had great advantage, but they were discarded because they were artificial and restricted the full potential force of the intervention. Preliminary discussions * supported the plan to employ an unfragmented, holistic teaching approach embodied in the guiding principles above. They also created the expectation of very limited gains from two intervention sessions totalling no more than three hours, in the belief that long established patterns of thought reinforced by use in and out

*Especially with Howard Gruber

of school require a long term impact in a substantial part of the daily life of the person if they are to be altered. In that context, three hours are insignificant.

The investigator spent three hours in two 1½ hour sessions with each subject in groups of one, two or three. The attempt was made to set up groups of two, but problems of scheduling and a few cancelled appointments necessitated the variations. The two sessions included the following components and, in general, in the sequence listed.

Purpose of study and thanks for their help

Discussion of unsolicited suggestions for the improvement of learning for college freshmen

Changing set: the nine dot problem (See Appendix 3 for this problem and those referred to below.)

Discussion of changing set and its application to problems raised by subjects (social and personal ones)

The School Cafeteria problem

Verbal tests, the number depending upon available time.

Sometimes the Balance and/or the Truck problem.

Results

The sample of 60 randomly selected freshmen was reduced to 58 because of incomplete results on two males in the first administration. In tests of difference between first and second administration scores of the same group the t test for correlated samples was used. Otherwise the t test for independent samples was applied (Ferguson, 1966). One-tailed test was employed in comparing first and second administrations, with the expectation of an increment whether

or not there was experimental intervention. The same was used in comparing male and female results on logical problems, expecting a difference favoring males. All other tests were two-tailed.

1. The Level of Logical Thinking in College Freshmen, by Sex and Related Variables (Table 1). The female (n,30) and male (n,28) samples are similar in respect to chronological age (about 18.4 years), number of high school science courses (about 2.2), college second semester grade point average (females, 1.90, males, 2.12 in a scale of 1 or A to 5 or F) and SAT Verbal (about 560).

For the following the differences in mean are significant. The women subjects have a higher high school rank at graduation, ranking at the 1.30 quartile versus the 1.75 quartile for men. The order is reversed for the SAT Mathematics with men scoring 617 and women 561. The differences in these two comparisons are significant at the .01 level.

In their performance on the three problems the mean scores of the men are significantly higher than that of the women, as follows: Rods, 3.36 for men and 3.03 for women (the difference significant at the .05 level); Balance, 3.32 and 2.67 (at the .01 level); Truck, 3.00 and 2.57 (at the .01 level). Comparing the mean of the means of the three problems the men are significantly higher at the .01 level, 3.23 versus 2.81.

Women outperform men in high school as this is reflected in high school rank but their performance in the college freshmen year is higher though not to a significant degree, as measured by second-term grade point average. Men outperform women on the SAT Mathematical and on the problems of the study. Their high school education in terms of number of high school science courses is the same.

A score of 1 is lower level concrete operations; of 2, upper level concrete; of 3, lower level formal operations; of 4, upper level formal operations. The man's mean score of 3.23 places it in the lower level of formal operations, about one-fourth of the way to the upper level of formal operations; while that of women,

Table I

Scores on First Administration
and Related Variables by Sex

Variable		M (n, 28)	F (n, 30)	F Ratio	t	Significance Level
CA (months)	$\bar{X}$	228	228	0.03		NS
	σ	5	6			
H.S. Science Courses (number of)	$\bar{X}$	2.18	2.20	0.01		NS
	σ	0.90	1.06			
H.S. Rank (by quartile)	$\bar{X}$	1.75	1.30	4.90	2.92	.01
	σ	0.89	0.65			
SAT-V	$\bar{X}$	554	562	0.14		NS
	σ	84	85			
SAT-M	$\bar{X}$	617	561	9.45	3.65	.01
	σ	57	78			
College GPA (2nd term)	$\bar{X}$	2.12	1.90	1.90		NS
	σ	0.51	0.67			
Rods	$\bar{X}$	3.36	3.03	3.64	1.90	.05
	σ	0.56	0.72			
Balance	$\bar{X}$	3.32	2.67	10.00	3.16	.01
	σ	0.72	0.84			
Truck	$\bar{X}$	3.00	2.57	13.40	3.64	.01
	σ	0.38	0.50			
(R, B, T)	$\bar{X}$	3.23	2.81	11.50	3.39	.01
		0.40	0.52			

2.81, is in the upper level of concrete operations, about four-fifths of the way to lower level formal operations.

The distribution of mean scores (Table IA) points up the difference in performance between the sexes. Using means of 2.00 and 2.33 as representing the concrete operational level, of 2.67, 3.00 and 3.33 as the lower formal level, and 3.67 as the upper formal level, the following differences emerge: concrete level, one male (3.5% of the men) and 9 females (30% of the women); lower formal level, 19 males (68%) and 18 females (60%); upper formal level, 8 males (28.5%) and 3 females (10%).

Table IA

Distribution of Mean Scores on First Administration by Sex

Mean Score		Male	%	Female	%
2.00		0)	3.5	4)	30.0
2.33		1)		5)	
2.67		5)	68.0	9)	60.0
3.00		4)		2)	
3.33		10)		7)	
3.67		8)	28.5	3)	10
4.00		0)		0)	
	Totals	28		30	

2. Relation Among Variables.

a) Comparison by Number of High School Science Courses (see Table II). Of the 58 subjects, 6 had no high school science courses, 4 had one, 22 had 2 and 26 had three or more. No differences among these four groups are significant, neither high school or college achievement

Table II

Number of High School Science Courses, Scores on First Administration and Other Variables (n=58)

	Number of Science Courses					
	0	1	2	3+	F Ratio	Significance Level
n	6	4	22	26		
CA (months)	227	230	228	227	0.37	NS
H.S. Rank (quartile)	1.00	2.00	1.82	1.31	3.31	NS
SAT-V	582	540	539	572	0.85	NS
SAT-M	602	603	565	601	1.16	NS
College GPA (2nd term)	1.68	2.08	2.18	1.92	1.40	NS
Rods	3.33	3.00	3.18	3.19	0.20	NS
Balance	2.33	2.75	3.04	3.11	1.57	NS
Truck	2.83	2.75	2.77	2.77	0.03	NS
$\bar{X}$ (R,B,T)	2.83	2.83	3.04	3.05	0.49	NS

or performance variables (SAT, high school rank, college grade point average) nor any of the problems in this study. Only one comparison approaches significance at the .05 level, high school rank. This is attributable to the high rank of the 3-plus group and of the even higher rank of the small no-course group. Their higher performance shows up also in grade point average and SAT-V. However, these differences are not significant.

b) Grades and Performance Variables (See Table IIA). The Pearson correlations for men between second term grade point average and high school rank (.23), SAT Verbal (.02) and SAT Math (.18) are not significant while that with the average of the first administration problems (.37) is significant at the .05 level. For women, the rs between grade point average and high school rank (.27), SAT Math (.27) and on logical problems (.09) are not significant while that with the SAT Verbal is significant at the .05 level. It should be pointed out that the problems were administered during the first term and the grades were end-of-second-term. In the meantime one of the men and four of the women were members of the experimental group. To the extent that the intervention had an effect upon grades, these r's are contaminated.

Table IIA

Pearson r's of Freshman 2nd Term Grade Point Average and Performance Variables for Random Sample

GPA With	Men (n, 28)	Signif. Level	Women (n, 30)	Signif. Level
High School Rank	.23	NS	.27	NS
SAT Verbal	.02	NS	.42	.05
SAT Math	.18	NS	.27	NS
$\bar{X}$ (R, B, T)	.37	.05	.09	NS

3. Comparison of Means of First and Second Administration Scores (Table III). For this purpose the randomly selected sample of 58 freshmen is further reduced by eliminating 3 subjects whose second administration scores are incomplete and 9--8 women and 1 man--who are in the intervention samples. The remaining n is 46, with 27 males and 19 females.

In a comparison of the total group on $\bar{X}$ (RBT) - $\bar{X}$ (RCS), that is first administration mean minus second administration mean, the mean of the first administration scores is 3.14 and that of the second, 3.22, a difference that is not significant.

A comparison of $\bar{X}$ (RBT) and $\bar{X}$ (RCS) for the 27 male subjects, 3.23 and 3.27, shows virtually no change at all. The 19 female subjects showed only slightly more gain, 3.02 to 3.16.

The Rods Problem is the only one given in both administrations. Men show a non-significant increase from 3.37 to 3.52. However the increase for women from 3.21 to 3.47 is significant at the .05 level, using a one-tailed test.

In summary there are no significant differences between first and second administration scores for the non-intervention sample, with the single exception of the Rods problem for women. This increase represents no more than one quarter of a step from the lower to the higher level of the formal operational stage.

4. Differences Between the Experimental and Control Subsamples (Table IV). From an original group of 25 (the lowest one-third on the first administration scores for the combined random and volunteer samples) attrition reduced this to 17, with 10 in the experimental and 7 in the control group. (Attrition occurred after random assignment to the two groups.) There are no significant differences between the two on any of the problems or either of the two means of the first and second administrations. The trend of scores shows that on the first administration the control group scores are higher on 2 of the 3 problems and

Table III

Comparison of First and Second Administration Scores

Sample(s)	n	Problem	$\bar{X}$	σ	t	Significance Level
Total	46	(R,B,T)	3.14	0.40	1.03	NS
		(R,C,S)	3.22	0.52		
			0.08	0.52		
Men	27	(R,B,T)	3.23	0.40	.51	NS
		(R,C,S)	3.27	0.44		
			0.04	0.37		
Women	19	(R,B,T)	3.02	0.37	.90	NS
		(R,C,S)	3.16	0.62		
			0.14	0.69		
Men	27	Rods (1st)	3.37	0.56	1.07	NS
		Rods (2nd)	3.52	0.51		
			0.15	0.72		
Women	19	Rods (1st)	3.21	0.53	2.04	.05
		Rods (2nd)	3.47	0.77		
			0.26	0.56		

Table IV

Differences Between Experimental and Control Subsamples

Experimental (n=10); Control (n=7)

	Sub-Sample	Mean	Standard Deviation	F Ratio	t	Significance
1st Administration						
Rods	E	2.20	0.42			
	C	2.57	0.79	1.60	1.27	NS
Balance	E	1.90	0.57			
	C	1.71	0.49	0.49	.70	NS
Truck	E	1.90	0.74	0.6		
	C	2.14	0.38	0.63	.80	NS
$\overline{X}$ (R,B,T)	E	2.07	0.26			
	C	2.19	0.32	0.75	.87	NS
2nd Administration						
Rods	E	3.00	0.82			
	C	2.71	0.95	0.44	.66	NS
Chemical	E	2.20	1.14			
	C	2.14	1.07	0.01	.10	NS
Shadow	E	2.30	0.48			
	C	2.57	1.27	0.39	.62	NS
$\overline{X}$ (R,C,S)	E	2.53	0.57			
	C	2.43	0.92	0.08	.28	NS

the mean; on the second administration, the reverse is true.

5. Difference Between First and Second Administration Scores (Table V). The non-intervention sample increased its mean score from 3.14 to 3.22, a gain of 0.08. The control group increasedits mean from 2.19 to 2.43, a gain of 0.24. Neither of these gains is significant. For the experimental group the increase of 0.47, from 2.07 to 2.53 is significant at the .01 level.

Over a period of about 6 months the non-intervention sample composed of the upper two-thirds of the distribution on the first administration gained less than 1/12th of a level; the control group gained about 1/4 of a level, and the experimental group, 1/2 of a level. Insofar as individuals are concerned, 6 experimental and 5 control subjects showed a gain; one experimental and two control subjects showed a loss.

Conclusions and Discussion

1. The level of logical thinking in first term college freshmen, as measured by the instruments of this study, is higher in men than women (Table I). The randomly selected sample of regularly admitted male freshmen performs at between the lower and upper levels of formal operations but the mean is closer to the lower level (3.23), while the sample of females score between the upper level of concrete operations and the lower level of formal operations but closer to the latter (2.81).

These data should be viewed against a background of the relative ability of these students, at least in terms of standard criteria. They are above average on the SAT (Verbal: 554 for men and 562 for women; Math: 617 for men and 561 for women). They are also clearly above average in high school quartile rank, with the women significantly superior (men, 1.75, women, 1.30).

Insofar then as these randomly selected samples are representatives of freshmen in four-year colleges, at

Table V

First and Second Administration Scores
for Intervention and Non-Intervention Samples

	M		Administration 1st	2nd	Difference	t	Significance Level
Non-Intervention	46	$\bar{X}$	3.14	3.22	0.08	1.03	NS
		σ	0.40	0.52	0.52		
Intervention							
Experimental	10	$\bar{X}$	2.07	2.53	0.47	3.09	.01
		σ	0.26	0.57	0.48		
Control	7	$\bar{X}$	2.19	2.43	0.24	.73	NS
		σ	0.32	0.92	0.88		

least those of comparable functioning ability, students are operating at a disadvantage because of the developmental level of their operational thinking.

What is the disadvantage of college freshmen who are either at the upper level of the concrete operations stage or the lower level of formal operations (Table IA)? Those still at the former stage, unable to engage in hypothetico-deductive reasoning or seriously limited in that ability, are restricted to givens. These givens can be compared and classified but not subjected to propositional logic. Whether in history or physics, mathematics or literature the student is limited to that which is presented to him; he can not postulate hypotheses based on what is possible (but not actual or given) and engage in the active process of verification of the hypotheses. For example in the Rods problem the subject is not given a long thick wooden rod which would provide him with concrete evidence that wood is the most flexible of the materials. Those at the concrete operational level either do not recognize the absence of this missing set of variables or do not hypothesize its flexibility, in comparison with that of other sets of variables (i.e., other rods), which can be tested by use of implication.

At the concrete level the student accepts the givens as reality because he is stuck with them; that is all he has available to him. In this study and presumably in any of his subject fields he is lost if an author, a lecturer or a discussant fails to provide every datum and every step in a logical process, a most unlikely condition in higher education where propositional logic is presumably the most common denominator of all activity. With those limitations a college student must resort to memory, that is, to meaningless (or only partly meaningful) memorization of the conclusions of an author without understanding the process, and to meaningless (or only partly meaningful) memorization of problem-solving methods which can then be applied only in rote fashion to familiar problems.

The college students at the lower level of formal operations have considerably less of a disadvantage. Their handicaps are nonetheless substantial. In particular they will lack an organized plan to solve the

problem at hand which the individual at the advanced level of formal operations proceeds to carry out systematically. In those many instances of problem solving (e.g. in the social and behavioral sciences) in which multiple variables appear in an associated state, it is necessary to apply the method of "all other things being equal." This is still in the process of development (if it is to develop at all) during the period of the lower level of formal thinking.

Since the sample of females in this study have a significantly lower score than the males it is worth comparing their academic performance to note the effects of their "disadvantage." Their high school rank is significantly higher. Their first year college grade point average is higher than that of the [illegible]n but not to a significant degree. These results are subject to several different but not conflicting interpretations. For one, they are consistent with the observation that attributes besides intellectual ones (e.g., conscientiousness as a student) contribute to academic success but that they compensate less for cognitive shortcomings at the college than at the high school level. For another they are consistent with the observation that the academic subjects most dependent upon logical thinking by their very structure (e.g., mathematics and the physical sciences) are also more associated with masculine role expectations and have proportionately heavier male enrollment, while subjects less dependent upon logical thinking by their structure (e.g. foreign language and some of the arts) have proportionately heavier female enrollments. The correlations in Table IIA lends some support for they show that the only significant r with gpa for the men is with the logical problem score while for the females the only significant r is with the SAT Verbal.

A recent study by Keasey (1972) provides some confirmation of the representativeness of the performance of the women subjects in this investigation. Her subjects, 24 women aged 17-19 at Trenton State College, took two of the same problems (Balance and Rods) and one different from ours (Pendulum rather than Truck). The mean score of her subjects is identical to that of the women in this study. There

is only an appearance of difference because of a variation in the scoring system: The Keasey mean is 4.81, ours 2.81 with 5 and 3 respectively representing the lower level of formal operations.

2. Between the first and second terms the mean of the mean scores of the freshmen did not increase significantly (Table III). That is true for the total random sample and for the male and female subsamples. For the control subsample of the intervention group the gain is not significant. However, for the experimental subsample it is significant (Table V).

The findings suggest that the experience of the college freshman year does not itself have a material effect upon the development of formal operational thinking, at least insofar as that is reflected in scores on the problems used in this study during a less-than-academic-year span. The findings also suggest that intervention of brief scope (two 1½ hour sessions) leads to a significant increase in mean scores on the problems, at least for those who in the first administration score in the lowest third of the distribution.

The professional significance is small when examining the changes in individual subjects in the experimental and control groups. Nonetheless, the fact that a brief instructional program should yield a significant difference between groups points to the desirability of designing a longer-term instructional plan and assessing its effects upon thinking in the college age population.

Keasey (1972) used a different and briefer form of training which was successful for training purposes and (for college students particularly) effective in delayed posttest on a familiar type of problem. There was, however, little generalization on the delayed posttest (one week after the posttest). Keasey considered the concept of horizontal decalage as one possible explanation; this refers to operations applicable to some tasks but not yet to others. Another and not conflicting one is that formal operations develop over many years and possibly their application to different areas "is a lifelong endeavor."

In two studies a year apart of the performance of children between the ages of 9 and 16 on a problem-solving task, Neimark (1967, 1968) found consistent improvement over the year. Considering the question whether improvement is continuous or represents "a series of relatively discrete 'decalages,'" she reports her data suggesting the latter; that is, the qualitative changes underlying performance improvement (such as formulating a rule to bring information, including self-stimulated information, under the individuals control) occur step by step, not continuously. It is probable that such an explanation is appropriate for findings like those of Keasey's and ours in which individuals progress to the formal operational level on some problems but not on others. The modal performance of college freshmen is, as these two studies show, at the lower level of formal operations. They can deal with propositions. They can act not simply on relationships between objects but on relationships between relationships. But just as the preoperational child between 4 and 7 acquires permanence of quantity before that of weight, it appears that adolescents acquire the use of some formal operations before acquiring others. Variations among them may be attributable to an experiental factor also because problems that appear to call for the same operations, e.g. the Balance and the Truck problems, both involving proportionality, also call into play knowledge of some different variables as for example friction and inertia in the Truck problem.

The possibility that any given portion of the population (perhaps including almost all of it) is capable of achieving the top level formal thinking is a moot question. To the extent that educational systems seek to enable individuals to enlarge their intellectual capacities, the attainment of that level ought to be an objective kept in mind in planning both the process and content of educational experience.

Two very recent studies suggest that such planning could achieve fruitful results in the intellectual development of college students. Mayer and Greeno (1972) found that two different methods of teaching the concept of a binomial probability to college students yielded structural differences in the learning outcomes. They were interested more in qualitative (i.e., structural) differences in the concept learned than in the quantitative differences. Presumably because the different instructional procedures activated different aspects of the students' existing cognitive structures, the effects were very different. One type of procedure produced significantly better transfer performance on certain kinds of problems, and the other teaching approach produced better transferability on other kinds of problems.

The second study has implications at a more global level. Chickering (1972) studied the objective and subjective environments of 13 small colleges with particular reference to the intellectual experience of the students. There were clear differences among them in the degree to which students were passive listeners, note-takers and memorizers in contrast with active discussants, synthesizers of ideas and appliers of principles to new problems. "At the two colleges where listening, talking, and thinking were more evenly balanced, less time was spent on memorizing, and more on the higher level mental activities." (p. 137) Differences in the role of the teacher varied similarly among the colleges with varying emphases on dispensing knowledge, managing the efforts to help students learn and sharing learning experiences with his students. According to Chickering, if academic experiences are to be improved, efforts should be directed to the relations between students and teachers and "the expectations and conceptual frameworks which influence the way they work together." (p. 143)

Facilitating the development of the highest levels of thinking probably does call for both micro-level changes in the nature of the learning experience and also those macro-level changes that are of an institutional character. These two are, in fact, inseparable with the latter having great impact on the former, that is on the outlook of the faculty, their teaching methods and expectations and the reciprocal behavior of students.

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Appendix 1

Directions for Administering Problems

Rods

This problem is about the flexibility of these rods. You see, they bend--some more than others.

(1) Your first problem is to find out which bends most and which least. The rods, as you see, are different in length, thickness, and material.

You use this holder. You stick a rods in this hole and tighten with the screw. And you use these weights on the edge of the rod.

(2) Next, what factors at work here? What factors (or variables) influence flexibility?

(3) Prove it (for each factor), i.e., length, thickness, material.

Balance

In this problem the materials are the balance--you know, like an old fashioned scale--and these weights.

The problem is to find out how you get balance or equilibrium.

(Later) Now, how do you explain it? What accounts for it?

Truck

Here we have a toy truck. Attached to it is a bucket. Here are some weights with the ounces marked on them. The truck is on this road which can be raised or lowered.

The problem is how you get the truck to move or how you get it to stand still (or to be at equilibrium) at different levels.

(Later) How do you explain it?

Prove it. or How did you discover it? or Test it out? or Show me how you got to that.

Chemicals

As you see this problem uses chemicals.

E points to glasses A and B (A contains 1 + 3; B contains 2) and says: Notice what happens when I take a few drops of this chemical marked "g" and put some in glass A and then some in glass B. What happened? Yes, the liquid in glass A turned yellow, while the liquid in glass B did not change color.

Now, here are 4 test tubes marked 1 to 4, and here is a test tube labeled "g." I would like you to reproduce the yellow color, using tubes 1,2,3,4, and "g" as you wish.

If S asks how many may be used, repeat the last sentence.

Shadows

You see this screen, this light and these four rings. The problem is to produce two shadows of the same size, using two different-sized rings.

Now, I'd like you to explain why two rings of unequal size produce two shadows of equal size.

Prove it.

Appendix 2

Scoring Criteria

Rods

II-A Describes but does not classify or compare

II-B Classifies and compares, accepting the observation of givens as reality

III-A Formulates hypotheses (as opposed to II) and attempts at proof; more active set than in II

III-B Provides active proof involving "all other things being equal," as follows (the symbol $>$ meaning more flexible)

Long thick wood $>$ long thick brass; long thin brass $>$ long thick brass; therefore, long thin wood, if available and tested, would be $>$ all of the others.

Balance

II-A Weights are equalized and added exactly; distances are added and made symmetrical. But coordination between weights and distances still intuitive. (p. 169)

II-B Now handles unequal weights and distances by displacement (not by substitution; i.e., + and, as in II-A) but still qualitatively, not by metrical proportion.

III-A Transition to metrical proportion but without comprehension of the factor involved.

III-B The law: Distance (or height) is compensated for by weight,--in mathematical terms.

Truck

II-A Explains in terms of own action with the equipment, i.e., it moves because you push or pull it, and because you put weights in, etc.

II-B Understanding at this stage of the following:

(1) equilibrium not due to equality between weights
(2) the role of inclination, i.e., more work needed to push a wagon up a steeper incline

III-A Formal thought: Considers entire set of possibilities and selects crucial cases as a test: extremes and middle. Seeks to coordinate the three factors into a single law, but angle not height.

III-B Law: 3 factors, inclusive (i.e., height, weight and counterweight, and in mathematical terms).

Chemicals

II-A Has operation of 1 to 1 correspondence but 2 x 2 combinals are rarely present. Therefore, no true combinatorial operation has appeared.

II-B Is capable of more sophisticated correspondences 2 x 2, 3 x 3, etc. but lacks systematic efforts at combinations.

III-A Systematic use of n x n combinations

Subjects evidence combinatorial system

Operation of reciprocity

III-B Same as III-A except system is now at equilibrium, is more stable and more sophisticated in the sense that subjects have a clear aim toward proof from the beginning.

Shadows

Stage II-A Knows that the size of shadows depends on the size of the object

Stage II-B Knows that the closer the object to the screen the smaller the shadow

Stage III-A (1) Calculates distances from light source rather than from screen
(2) Takes into account distance between light source and first r'ng, not simply distances between two rings

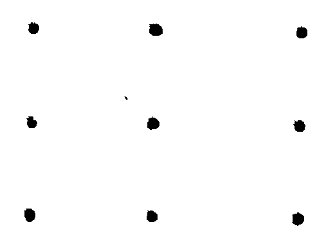
Stage III-B Law is generalized,--not satisfied with hypothesis on a single case--conceives of relationship as changeable and capable of taking series of equivalent forms.

Appendix 3

Problems Used for Intervention*

Nine Dot Problem

Use four connected lines to cover all of the dots.



School Cafeteria Problem

Children in an elementary public school became ill one hour after lunch due to some contamination. Here are the known facts. After you read them, tell me all of the possible reasons for the contamination.

1. All the children in the first grade are ill
2. Only the boys in the 3rd grade are ill
3. Only the girls in the 5th grade are ill
4. None in Kindergarten or 2nd, 4th, 6th are ill

The lunch included the following

1. orange <u>or</u> tomato juice
2. hamburger on a bun
3. lettuce and tomato
4. chocolate pudding <u>or</u> cup cake

The kitchen and service workers had the following schedule

Some work from 7 a.m. - 12 noon
Others work from 8 a.m. - 1 p.m.

a) one of the two salad makers worked in the early shift; one in the late shift
b) same for the two hamburger servers
c) same for the two dessert preparers

---

*Sometimes the Balance and/or the Truck problem were also used.

Lunch schedule

1. Kindergarten, 2nd, 4th, 6th graders eat 11:30 - 12 noon
2. 1st, 3rd, 5th graders eat 12:15 - 12:45
3. 3rd grade girls and 5th grade boys take gym last period before lunch and come to the lunch line about 5 minutes late

Verbal Tests

1. Four people are cut on a date: John, Linda, Fred and Mary. They are going to a party on the 5th floor of a house. To get up they take an elevator that has capacity for only 2 people at a time. What are all the different ways they could pair up to ride the elevator?

2. In one city in New Jersey college students were discussing the local school system. In particular they discussed the different groups that ought to have a right to speak at a forthcoming meeting about school policy and the chairman of the meeting agreed to follow their recommendations. Students should, but not students who go to private or parochial schools. Parents should, but again not those who send their children to private or parochial schools. Parents who don't have school age children should not, but they have a right to attend the meeting. The teachers in the school system should.

(1) The chairman calls on a student in the city high school. Was he right to do that?
(2) The chairman does not recognize a parent whose child goes to a parochial school. Was he right?
(3) The chairman does not call on a parent whose children have finished school. Was he right?
(4) The chairman calls on a student in one of the city elementary schools. Was he right?

3. Ford Motor Company makes many different models including a new car called a Pinto. The engineering department gets reports about the safety of their cars from insurance companies and from owners of Ford cars.

In the first month after the Pinto went on the market, the engineering department got reports on accidents with the Pinto in which the brakes didn't work. The engineers held a conference about the safety of the Ford cars, and considered insurance accident reports.

(1) The first one told about an accident in which the brakes didn't work. Then the car must be a Pinto. Am I justified in saying that?
(2) The second accident report was about the Ford Maverick. Then the accident was not due to a defect with the brakes. Am I justified in saying that?
(3) The third accident report was about a car that had an ignition defect. Then it can't be a Pinto. Am I justified in saying that?
(4) The fourth accident report was about a car that had a brake defect. Then it must be a Pinto. Am I justified in saying that?

4. Among the many great and courageous black leaders in America Dr. William E. Dubois and Dr. Martin Luther King distinguished themselves as heads of great organizations, and Dr. Franklin Hope and Dr. Dubois are known as great historians. Which one was both a head of a large organization and an historian?

5. A college freshman comes back after the spring vacation and tells her roommates: Don't ever go swimming after you've been dancing a long time. A friend of mine did it and got bad cramps. Was she justified in saying that?

6. A three month old male cat can run 8 miles an hour. A three month old male beaver can run 6 miles an hour. An adult male cat can run 13 miles an hour. An adult male beaver can run 10 miles an hour. An adult female cat can run 11 miles an hour. An adult female rabbit can run 12 miles an hour. Which of the species is the fastest? The slowest? What do you have to take into consideration in reaching that answer? How did you do it?