DOCUMENT RESUME

ED 276 618 SE 047 615

AUTHOR Kuehn, Christine; Krockover, Gerald
TITLE An Analysis of Fifth and Sixth Grade Students' Acquisition of the Inventing Process.
PUB DATE 86
NOTE 29p.
PUB TYPE Reports - Research/Technical (143)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Academic Achievement; Creative Thinking; *Creativity; *Discovery Processes; *Elementary School Science; Grade 5; Grade 6; Instructional Effectiveness; Instructional Improvement; Intelligence; Intermediate Grades; *Inventions; Measurement Techniques; Process Education; Science Education; *Science Instruction; *Scientific Attitudes
IDENTIFIERS *Science Education Research

ABSTRACT

The purpose of this study was to determine whether an instructional unit on inventing affected the inventive abilities of fifth and sixth graders and investigate the possible effects of the unit on students' creativity scores and attitudes towards science. Concomitantly, this study attempted to determine whether relationships existed between students' inventive abilities and the following: achievement, intelligence, creativity, and creative interests. One-hundred-seven fifth and sixth graders in three elementary schools were randomly assigned by school to experimental and control groups. Analysis of the data revealed a number of significant interactions. For the measure of inventing, instruction by sex and school by grade were significant interactions. Achievement as a covariate was also found to be significant. The interaction, school by grade by sex, was significant for creativity. There were no significant correlations between inventing, creativity, and attitude towards science, as measured by this study, although changes in creativity scores and attitudes towards science scores occurred. The results of this study suggest that instruction does increase inventiveness for some students. (Author/TW)

An Analysis of Fifth and Sixth Grade Students' Acquisition of the Inventing Process

Christine Kuehn

Gerald Krockover

ABSTRACT

The purpose of this study was to determine whether an instructional unit on inventing affected the inventive abilities of fifth and sixth graders and investigate the possible effects of the instruction unit on students' creativity scores and attitudes towards science. Concomitantly, this study attempted to determine whether relationships existed between students' inventive abilities and the following: achievement, intelligence, creativity, and creative interests. One hundred seven fifth and sixth graders in three elementary schools were randomly assigned by school to experimental and control groups. The experimental groups received instruction in the process of inventing followed by participation in a Rube Goldberg lesson and invention fair. The control group participated only in the Rube Goldberg lesson and invention fair. A posttest only control group design was used. Multivariate analysis of covariance was used to adjust posttest scores using pretest scores, achievement and intelligence test scores.

Analysis of the data revealed a number of significant interactions. For the measure of inventing, instruction by sex and school by grade were significant interactions. Achievement as a covariate was also found to be significant. The interaction, school by grade by sex, was significant for creativity. There were no significant correlations between inventing, creativity, and attitude towards science, as measured by this study, although changes in creativity scores and attitude towards science scores occurred. The results of this study suggest that instruction does increase inventiveness for some students.

Introduction

Invention is one of the strongest driving forces in human affairs and it is the very foundation of civilization. Unless there is an understanding of invention, there can hardly be any comprehension of the past, present, or future (Shlesinger, 1973). Inventions cause change, development, and evolution in world affairs. Inventive thought should be encouraged for the purpose of solving problems for humanity since the key to many new products and inventions which will transform the environment and supply many of the needs of society may well be the knowledge of how to invent.

It is possible that any problem for which no solution has been found may, in fact, be insoluble. More likely, the means for solving the problem is wrong or inadequate and, therefore, some new and original approach is necessary. Progress and perhaps mankind's existence itself depends on such new and original approaches to solutions which come from the creative or inventive process. These new ideas do not come from complex machines, ultramodern facilities or dollars, but from people (McCormack, 1981; Gilmore, 1959).

Purpose

The purpose of this study was to determine whether an instructional unit on inventing affected the inventive abilities of fifth and sixth graders and to investigate the possible effects of the instructional unit on students' creativity scores and attitudes towards science. Concomitantly, this study attempted to determine whether relationships existed between students' inventive abilities and the following: achievement, intelligence, creativity, and creative interests.

Methodology

Sample

The study involved 107 elementary school students enrolled in three elementary schools within one midwestern, rural school corporation. The sample consisted of all fifth and sixth grade students, each school having one class at each grade level. The schools were randomly assigned to experimental and control groups. The experimental group consisted of two schools (two classes at each grade level) and the control group consisted of one school (one class at each grade level). In the experimental group which received instructional treatment were 38 fifth graders and 41 sixth graders. In the control group which received no instructional treatment were 19 fifth graders and eight sixth graders. The total number of students participating at sometime during the study was actually 117. Due to experimental mortality, ten subjects were eliminated from the study. The students eliminated from the study were distributed among all three schools.

Procedures

A two-day in-service program was conducted to familiarize all of the teachers (K-6) in the three elementary schools with the instructional unit used in this study. Information concerning the type of activities appropriate for teaching inventing as a process, as well as the thinking skills necessary for the development of inventive abilities, was presented. Most of the time was spent doing the activities included in the instructional unit. The investigator conducted the in-service program and served as a model teacher.

During the last two weeks of the first semester, three pretest measures were administered, each given on separate days. At the beginning of the second semester, the experimental group of classes experienced the instructional treatment. The control classes received the science instruction which was normally a part of the curriculum. The investigator met with each of the teachers reviewing the information provided during the in-service and answering questions regarding specific lessons to be taught and materials to be used.

Treatment

The instructional treatment involved the implementation of an instructional unit which consisted of 14 lessons that stimulated creative thinking, visual thinking, inventive thinking, provided a science knowledge base, and encouraged the development of manual skills. The unit was based on a model of instruction which requires an active role on the part of the student and emphasized the science process skills. Some of the lessons included in the instructional unit were original activities while others were either taken or adapted from a variety of sources. Each lesson was assigned an estimated amount of time necessary for completion; the length of time for each lesson varied from 30 to 80 minutes. The total estimated instructional time was ten hours and forty minutes taught over a four week period.

The instructional unit was submitted to a panel of three science educators. Each panel member independently rated each lesson within the unit on its appropriateness for development of various skills such as visual, creative, and inventive thinking. Panel members agreed that each of the lessons were highly appropriate. This consensus was used as evidence of content validity.

The last lesson in the unit presented information regarding Rube Goldberg inventions. That lesson was presented to subjects in the control group as well as subjects in the experimental group. At the conclusion of the lesson, all subjects were given a challenge to individually design and construct an invention to wake themselves in the morning. The inventions, in the true tradition of Rube Goldberg, were to be as complicated and as humorous as possible. The inventions were displayed at individual school invention fairs and evaluated by three judges using the Invention Evaluation Instrument. The three persons who judged the inventions were graduate students in science education. The time between the initial student instruction and the invention fair was approximately six weeks. The time between the final instruction and the invention fair, approximately two weeks, was allowed for the independent construction of an invention. Some school time during those two weeks was allocated to invention design and construction. Subjects were allowed to work on their inventions at home, as well. The total amount of time involved in designing and constructing the inventions varied according to individual subjects.

Instruments Used in the Research

Estes Attitude Scales. The Estes Attitude Scales, Elementary Form (EAS; Estes, Estes, Richards, & Roettger, 1981), a device for measuring students' attitudes toward basic school subjects, reading, mathematics, and science, consisted of three 14-item Likert-type scales. The EAS results in the form of scaled scores provide a means of 1) estimating how attitudes of groups or individuals compared with similar aged peers, 2) determining magnitude and direction of attitude change over a period of time, and 3) comparing relative attitudes of groups or individuals toward the subject areas surveyed. The scales, intended for use with children from grades two through six, required no reading. The entire battery was administered in one session taking approximately 20 minutes, although only the attitude towards science portion was utilized in this study. The reported reliability of the Elementary Form ranges from .76 to .88 on all three scales. The internal consistency on the science scale, alone, ranges from .82 to .88. The reliability for 105 subjects used in this study was .90 established using the equal length Spearman-Brown split half correlation.

Group Inventory for Finding Interests. The Group Inventory For Finding Interests (GIFFI; Rimm & Davis, 1980) was used to identify students with attitudes and interests usually associated with creativity. These attitudes included independence, perseverance, flexibility, curiosity, breadth of interests, sense of humor, and risk-taking. The GIFFI Level 1 instrument consisted of 60 items marked on a Likert-type scale taking approximately 30 minutes to administer. Curve Equivalent scores provided results in five dimensions: 1) creative art and writing, 2) challenge-inventiveness, 3) confidence, 4) imagination, and 5) many interests. Using Hoyt reliability correlations, the internal consistency was reported to be .88 and by correlating inventory scores with outside measures of creativity, the criterion-related validity was established and ranged from .33 to .49.

Purdue Creativity Test. The Purdue Creativity Test (PCT; Lawshe & Harris, 1960) was used to measure creativity. The purpose of this test, originally, was to find out how "fluent, flexible, and original" engineering personnel were in their thinking. The test consisted of 20 items, each requiring two minutes. There were three kinds of items, all based on three-dimensional drawings. The first eight items asked for a list of possible uses for a single object. The next four items asked for a list of possible uses for two objects together. The last eight items asked for a list of possible identifications for an object. From the three types of items, two subscores were obtained, fluency and flexibility. The flexibility scores were based on items one through 12, a combination of the first and second types of items. From the third type of items, the fluency score was obtained. Two reliability estimates were reported for the flexibility score. The interscorer correlation was .87 and the split-half reliability coefficient was .86. For fluency and total scores, respectively, the split-half reliabilities of .93 and .95 were reported. For the total score, the interscorer correlation was .97 (Lawshe & Harris, 1960).

Since the PCT was not originally designed to be administered to elementary school students, it was necessary to determine whether the PCT could be effectively administered to fifth grade students and whether the test discriminated between fifth grade students' responses to the items. A pilot study was conducted which involved 26 fifth grade students. The PCT was administered and scored as indicated in the directions. The results of the pilot study showed that the students, within the 2 minute time periods, could produce a number of responses for items one through 12 involving each of the 12 established categories. Two responses, those referring to living things, could not be classified into one of the 12 categories and were eliminated.

To confirm the accuracy and consistency of scoring, an individual trained by the investigator in the scoring procedures, scored ten tests randomly selected from the pilot study. After establishing normality and homogeneity of variances, an analysis of variance was performed indicating the differences between the judges to be nonsignificant for the fluency subtest. There was a judge by question interaction on the flexibility subtest which was significant at the 0.01 level. Examination of the data revealed that, on test item number four, the two judges consistently classified two objects into two different categories. When that test item was removed from the data and a subsequent ANOVA was performed, the difference between judges was found to be nonsignificant on the flexibility subtest.

Further analysis of the PCT was performed using the 107 subjects involved in the study. Reliability on the total score for the pretest, using equal length Spearman-Brown split half was .72. Condescriptive analysis revealed a mean of 53.53, variance of 316.73 and a range of 88.0 for the total score on the pretest, and a mean of 60.14, variance of 432.70 and a range of 127.50 for the total score on the posttest. The PCT manual (Lawshe & Harris, 1960) included a table, Norms Based on Professional Engineers (N=106), which indicated the range for 1%ile to 99%ile as being 30 to 105 with a mean of 63.0. Other figures in the manual, empirical individual expectancy charts for product, process, and project engineers (N=104) indicated ranges from 30 to 119.

Invention Evaluation Instrument. The Invention Evaluation Instrument was developed by the investigator to be used by judges to evaluate the students' Rube Goldberg-type inventions displayed at the invention fairs. Numerical scales were provided for assignment points to each invention in the following categories: 1) the number of steps involved in the invention, 2) the number of different sources of energy, 3) the success of execution, 4) the degree of humor involved in the invention, and 5) the degree or originality in the materials and steps involved in the invention. The first three categories were objective in their measurements; to determine the score for each of the first two categories, steps or sources of energy were counted. The third category was scored according to the number of times the inventor assisted during the performance of the invention. In an attempt to make the fourth category as objective as possible, the judges were instructed to evaluate the degree of humor involved in the invention as a reflection of the reaction of the crowd present during the performance rather than a personal reaction to the invention. To aid in the scoring of the fifth category, the judges surveyed all the inventions, assessing the variety of materials involvec in the individual inventions, before the formal judging commenced.

The Friedman Test, a form of rank-order analysis of variance, was used to determine the reliability of the judges using the IEI. The results showed a Chi-square value of 0.000 and a significance of 1.000 indicating the difference between the judges was not significant. The ranking of inventions using the IEI, was therefore, shown to not depend on the person doing the scoring.

By definition, a Rube Goldberg invention must be complex and humorous. Complexity was measured in the first two categories on the IEI; humor was measured in the fourth category. The fifth category was included to measure the degree of inventing involved, inventing being defined as a unique combination of materials and processes. The third category was included as incentive for the subjects. The students had copies of the IEI previous to the construction of the inventions and each student evaluated his/her own invention prior to the official judging by the three judges. The third category has been considered unnecessary for both the definitions of inventing and a Rube Goldberg invention. After the analysis of the IEI, itself was completed, the analysis of the data in this study was conducted two ways, 1) using the sum of all three judges scores on all five categories in the IEI and 2) using an adjusted total of the sum of all three judges scored including all except the score on the third category. The rationale for adjusting the total IEI was based on the observation that inventions which were very simple, one or two steps, involved little risk; it was essentially impossible for the invention to fail to perform. On the other hand, those inventions which were very complex, five or more steps, involved considerable risk in performance. The inclusion of category three tended to discriminate against those inventions and therefore, the purpose for the IEI.

Other Instruments Used in the Study

Achievement and intelligence test scores were secured from student records. As a measure of achievement, all three schools had administered the Iowa Test of Basic Skills (ITBS). As a measure of intelligence, some of the subjects had taken the Lorge-Thorndike Intelligence Tests (LTI) and others had taken the Cognitive Abilities Test (CAT).

Testing Procedures

Prior to any student instruction in inventing, the EAS, the GIFFI, and the PCT were administered to each class involved in the study. The tests were administered on separate days. The EAS and the PCT were used as pre-test and post-test instruments. The second administration of the tests followed the invention fair. Time involved in testing was not included in the instructional time.

Research Design

This study used a 2 x 3 x 2 x 2 nested factorial, posttest-only control group design with instructional treatment as the first factor. The second factor was the three elementary schools. This factor was nested within instruction, and, therefore, instruction and schools were confounded. The third factor was the two grade levels (fifth and sixth) and the fourth factor was gender (male and female). Subjects were nested within each variable.

Method of Analysis

Multivariate analysis of covariance (MANCOVA) was conducted on the results from each of the post-measures to determine what effects the instructional unit may have had. The results of the three post-measures were used to establish four dependent variables: 1) Invention Evaluation Total based on the IEI, 2) Attitude Towards Science based on the EAS, 3) Creativity based on the total score for PCT, 4) Flexibility based on the subtest score of PCT.

Using MANCOVA allowed simultaneous evaluation of the four dependent variables while taking into account any initial differences between subjects through the use of seven covariates: 1) Achievement test scores, 2) Intelligence quotient, 3) Creativity interests (as measured by GIFFI), 4) Inventiveness (interest measured as subscore with GIFFI), 5) Creativity (as measured by PCT pretest), 6) Flexibility (as measured by a subtotal of PCT pretest), and 7) Attitude (as measured by EAS pretest). By using covariates, significant results were not repressed due to individual differences.

First, multivariate F ratios were examined. Where the multivariate F ratio was significant, separate univariate F ratios for each dependent variable were examined. The means, standard deviations, and adjusted means, using the seven covariates, for each dependent variable are presented in Table 1. The means and standard deviations for each of the covariates are presented in Table 2. The adjusted means of each group of subjects nested within the independent variables were used as the experimental unit for each of the dependent measures.

The results of multivariate tests of significance for each of the dependent variables is presented in Table 3. The effects of grade and the interaction between school and grade were shown to be significant at $p < .01$. Examination of the univariate analyses will further illustrate the importance of these two effects.

The results of the univariate F test for the dependent variable, invention, as reported in MANCOVA are presented in Table 4. Gender, as a main effect is significant at the $p < .05$ level. The mean scores for males are higher than the mean scores for females.

Instruction, as a main effect, appears to be significant at the $p < .05$ level. It is important to recognize the confounding of schools within instruction. The experimental group included two schools which allowed for comparison between schools. The control group included one school and did not allow for comparison between schools. The difference in inventiveness may be due to instruction.

Although not statistically significant at $p < .05$ level, the instruction by gender interaction at $p = .089$ may have practical significance, and at least be noteworthy. Table 5 presents the adjusted mean scores of the IEI for the effect of instruction by gender and Figure 1 displays the same information graphically. Scores for the students in the experimental group are higher than scores for students in the control group. The difference between the scores of the females in the experimental group and the females in the control group were much greater than the difference between the scores for the males in the experimental group and the males in the control group.

The interaction between school and grade is significant at the $p < .05$ level. Scores on the inventions for sixth graders were higher than for fifth graders in the control school and one experimental school. In the second experimental school the scores on the inventions were higher for the fifth graders than for the sixth graders. Achievement was the only covariate which was important for invention, significant at the $p < .05$ level.

The results of the univariate F test for the dependent variable, flexibility, are reported in Table 6. The interaction of school by grade by gender is significant at the $p < .05$ level. The mean scores for fifth graders were higher than the mean scores for sixth graders on both the pretest and posttest for flexibility. The gain between pretest and posttest for fifth graders appears to be essentially equal for all schools suggesting the gains have nothing to do with the instruction. The gains between pretest and posttest scores for sixth graders were not as large as the fifth graders but a similar pattern exists. The scores show significant increases in flexibility between pretests and posttests for females and little or no increase in scores for males. The only exception noted was one experimental group school where the gain scores for males and females were essentially equal. Covariates for flexibility which were significant at the $p < .01$ level were the pretest scores on the flexibility subtest of the PCT and the pretest scores for the total PCT.

The results of the univariate F test for the dependent variable, creativity, as measured by the total score on the PCT, are presented in Table 7. The results are very similar to the results of the flexibility subtest. The interaction of school by grade by gender is significant at the $p < .05$ level. The pretest of the PCT was the only significant covariate and it was significant at the $p < .001$ level.

The results of the univariate F test for the dependent variable, attitudes towards science are presented in Table 8. No effects are significant at the $p < .05$ level. The main effect, school nested with instruction is significant at the $p = .061$ level and may also be noteworthy. Two schools, the control school and one of the schools in the experimental group, showed increases in mean scores while the other school in the experimental group had essentially equal mean scores for pretest and posttest measures. The school which demonstrated no change had the highest mean scores at the beginning of the study. The schools which had lower pretest scores showed the greatest increases resulting in similar posttest measures for all three schools. Since the pretest scores of 26 students were at or near the ceiling for the test, the EAS posttest was not sensitive to increases in attitudes towards science. The EAS posttest was administered after the invention fair in each schools. Therefore, the posttest was most likely influenced by the Rube Goldberg activity and invention fair and did not truly measure the effect of instruction.

Conclusions

This study has shown that instruction has affected the inventive abilities of some students. Three of the four classes which received instruction, one fifth grade and two sixth grade classes, demonstrated higher mean scores on the inventions as measured by the IEI than the classes which received no instruction. Females who received instruction had much higher mean scores on inventions than females who received no instruction.

Males in each of the three schools had higher mean scores on inventions than females in the same school, but the males in only one school which received instruction showed higher mean scores than the males in the school which received no instruction. Instruction was apparently more important for the females in this study than for the males. The implications of these results are very important for science education at a time when educators are looking for ways to encourage science achievement in females.

If inventing were an inherent ability, only those students with high degrees of inventiveness would consistently score high on invention measures and students not inherently inventive would consistently score low on invention measures. Instruction would not affect changes in the mean scores when classes were compared. The results of this study indicate that instruction does increase inventiveness for some students. The fact that instruction enhances inventiveness supports the suggestion that inventing is a process skill which can be learned and that, perhaps, inventing should be included in the list of science process skills associated with science education.

REFERENCES AND SELECTED BIBLIOGRAPHY

Adams, J. L. (1976). Conceptual blockbusting, a pleasurable guide to better problem solving. San Francisco: San Francisco Book Company.

Arieti, S. (1976). Creativity: The magic synthesis. NY: Basic Books.

Arnheim, R. (1969). Visual thinking. Berkeley, CA: University of California Press.

Biondi, A. M., & Parnes, S. J. (Eds.). (1976). Assessing creative growth: The tests - book one. Great Neck, NY: Creative Synergetic Associates.

Buros, O. K. (Ed.). (1965). The Sixth Mental Measurements Yearbook. Highland Park, NJ: The Gryphon Press.

Butterfield, S. M. (Ed.). Inventions - Robots - Future. Santa Barbara, CA: The Learning Works.

DeBono, E. (1973). Lateral thinking, creativity, step by step. New York: Harper and Row.

DeBono, E. (1968). New think: The use of lateral thinking in the generation of new ideas. New York: Basic Books.

DeVito, A., & Krockover, G. H. (1980). Creative sciencing: A practical approach. Boston: Little, Brown and Company.

Estes, T. H., Estes, J. J., Richards, H. C., & Roettger, D. M. (1981). Estes attitude scales measures of attitudes toward school subjects manual for administration and interpretation. Austin, TX: Pro-Ed.

Gilmore, F. E. (1959). How to invent. Houston: Gulf Publishing.

Getzels, J. W., & Jackson, P. W. (1963). Creativity and intelligence explorations with gifted students. New York: John Wiley & Sons.

Hall, S. S. (1984). Eureka! Inventors, and how they get their wheels turning. Smithsonian, 111-125.

Keller, C. (1979). The best of Rube Goldberg. Englewood Cliffs, NJ: Prentice-Hall.

Kneller, G. F. (1965). The art and science of creativity. Chicago: Holt, Rinehart and Winston, Inc.

Kuechen, J. A. (1969). Creativity, invention, and progress. Indianapolis, IN: Howard W. Sams & Co.

Lawshe, C. H., & Harris, D. H. (1960). Purdue personnel tests, manual of instructions. West Lafayette, IN: Purdue Research Foundation.

Mayer, R. E. (1983). Thinking, problem solving, cognition. New York: W. H. Freeman and Company.

McCormack, A. J. (1976). Rube Goldberg, meet Thomas Edison. Learning, 70-74.

McCormack, A. J. (1981). Inventors workshop. Belmont, CA: Pitman Learning.

McCormack, A. J. (1984). Teaching inventiveness. Childhood Education, 249-255.

McCormack, A. J., & Doi, G. (1972). Creativity is a bunch of junk. Science and Children, 9-12.

McKim, R. H. (1972). Experiences in visual thinking. Monterey, CA: Brooks/Cole.

Moore, A. D. (1969). Invention, discovery and creativity. Garden City, NY: Anchor Books Doubleday.

Parnes, S. J., & Harding, H. F. (Eds.). (1962). A source book of creative thinking. New York: Scribners.

Random House dictionary of the English language, unabridged. (1966). New York: Random House.

Rimm, S., & Davis, G. A. (1980). Group inventory for finding interests manual for administration. Watertown, WI: Educational Assessment Service.

Rimm, S., Davis, G. A., & Bien, Y. (1982). Identifying creativity: A characteristics approach. Gifted Child Quarterly, 26(4), 165-171.

Rossman, J. (1964). Industrial creativity the psychology of the inventor. New Hyde Park, NY: University Books.

Schmidt, V. E., & Rockcastle, V. N. (1978). Teaching science with everyday things. New York: McGraw-Hill.

Shlesinger, B. E., Jr. (1982). An untapped resource of inventors: Gifted and talented children. The Elementary School Journal, 82(3), 214-220.

Shlesinger, B. E., Jr. (1973). The art of successful inventing. Washington, DC: Kelly, Hafner Associates.

Stanish, B. (1981). The unconventional invention. Hamilton, IL: Hamilton Press.

VonFange, E. K. (1959). Professional creativity. Englewood Cliffs, NJ: Prentice-Hall.

Webster's third new international dictionary, unabridged: The great library of the English language. (1966). Springfield, MA: Merriam-Webster.

Weiss, H. (1980). How to be an inventor. New York: Thomas Y. Crowell.

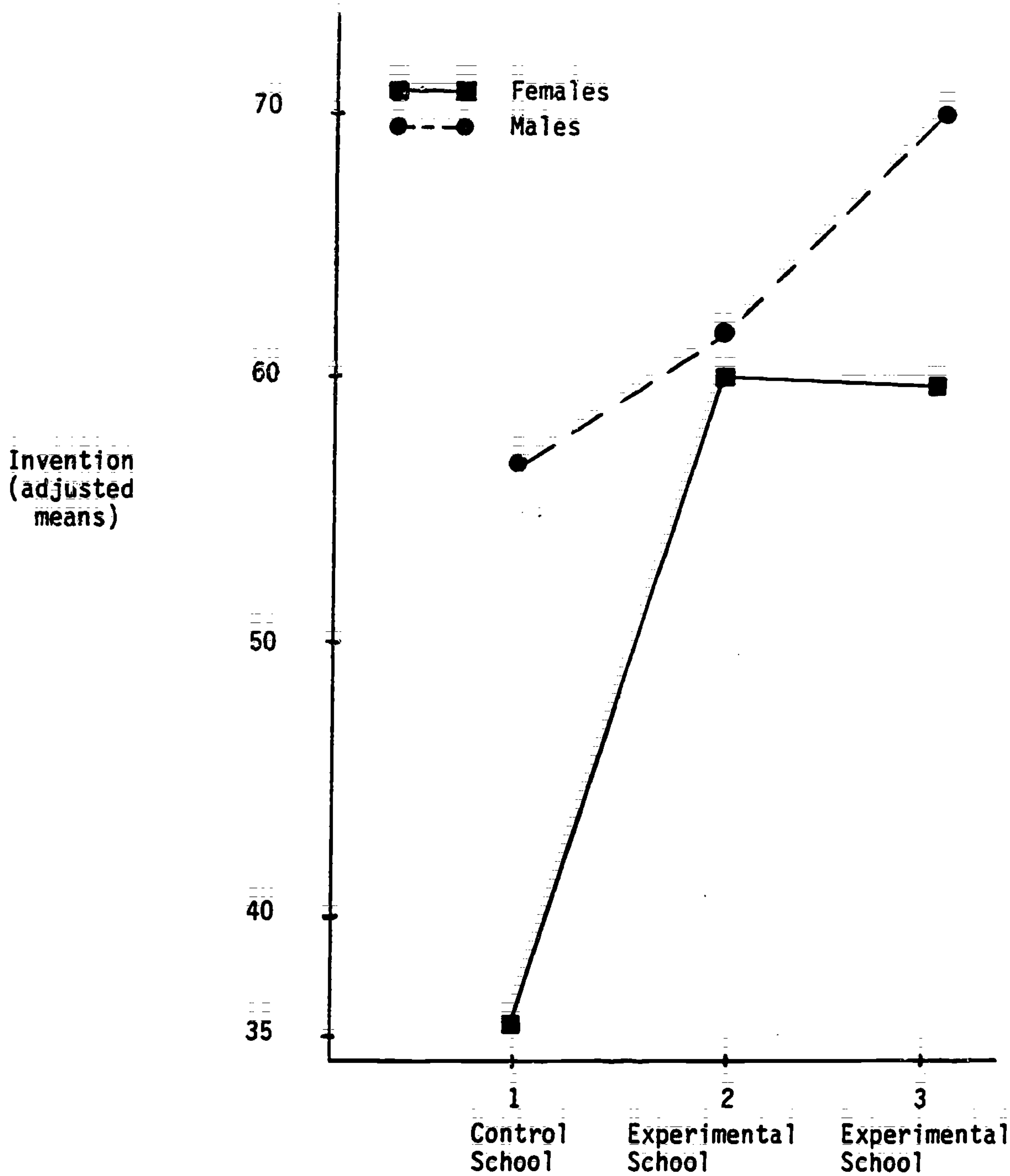

Figure 1. Effect of gender on invention

Table 1
Unadjusted and Adjusted Means and Standard Deviations for Dependent Variables

Dependent Variable	Instruction No	Instruction Yes	Schools 1	Schools 2	Schools 3	Grade 5	Grade 6	Gender f	Gender m
Invention[a]									
means	52.9	61.3	52.9	57.0	65.5	56.0	62.4	56.9	61.1
s.d.	13.1	17.0	13.1	16.4	16.6	13.3	18.6	18.3	14.9
adj. means	51.6	62.6	50.8	59.9	64.8	55.8	62.7	55.6	62.5
Flexibility[b]									
means	38.8	39.9	38.8	43.5	36.2	47.9	31.7	41.2	38.4
s.d.	12.3	14.4	12.3	16.3	11.3	13.3	9.0	15.1	12.8
adj. means	38.3	40.4	38.3	41.4	38.9	44.6	35.1	39.6	40.0
Creativity[c]									
means	58.3	62.6	58.3	68.3	56.9	74.3	49.5	64.3	59.5
s.d.	19.8	22.7	19.8	26.3	17.1	21.5	14.5	23.8	20.6
adj. means	57.2	63.6	57.3	66.4	59.8	69.8	53.9	61.3	62.5
Attitude towards science[d]									
means	49.5	53.3	49.5	52.5	54.2	52.7	52.1	51.8	52.8
s.d.	10.9	9.9	10.9	10.9	8.8	10.1	10.4	10.6	10.0
adj. means	52.5	51.2	54.5	53.7	49.9	52.5	52.3	52.1	52.5

Note. adj. means = adjusted mean for covariates.

[a]Maximum possible score = 150 as measured with the IEI.

[b]Maximum possible score = 144 as measured on the subtotal of PCT, posttest

[c]Maximum possible score = unlimited as measured on total fo PCT, posttest

[d]Maximum possible score = 00 as measured on Science subtest of EAS, posttest

Table 2
Means and Standard Deviations for Covariates

Covariates	Instruction		Schools			Grade		Gender	
	No	Yes	1	2	3	5	6	f	m
Achievement[a]									
means	64.6	71.2	64.6	67.9	76.4	75.0	66.0	74.1	67.6
s.d.	23.4	20.5	23.3	22.3	17.8	19.4	22.4	18.0	23.3
Inventiveness[b]									
means	4.8	4.3	4.8	4.5	4.2	4.8	4.1	3.7	5.0
s.d.	1.8	1.8	1.8	1.9	1.7	2.0	1.5	1.5	1.8
Attitude towards Science[c]									
means	42.5	51.3	42.4	47.7	55.0	49.3	49.2	48.5	49.8
s.d.	8.4	10.5	8.4	11.7	7.6	9.6	11.7	11.5	10.1
Creativity[d]									
means	57.7	52.1	57.7	56.7	47.6	61.0	46.2	53.2	53.6
s.d	20.0	17.6	20.0	19.0	15.0	19.0	14.2	17.2	19.1
Creative Interests[e]									
means	53.3	55.2	53.3	56.6	53.8	57.0	52.5	55.5	54.2
s.d.	19.5	18.5	19.5	18.9	18.4	18.7	18.6	18.5	19.0
I.Q.[f]									
means	106.0	108.7	106.0	106.5	110.8	107.4	108.6	110.4	106.3
s.d.	9.4	11.1	9.4	11.3	10.7	10.5	11.1	9.7	11.2
Flexibility[g]									
means	33.4	33.8	33.4	38.3	29.2	38.6	29.0	33.4	33.9
s.d.	10.1	12.1	10.1	13.2	8.9	11.4	9.7	10.8	12.1

[a]Maximum possible score = 99.

[b]Maximum possible score = 9 as measured by one dimension of GIFFI.

[c]Maximum possible score = 67 as measured on Science subtest of EAS, pretest.

[d]Maximum possible score = unlimited as measured on total score PCT, pretest.

[e]Maximum possible score = 99 as measured on total of GIFFI.

[f]Maximum possible score = unlimited.

[g]Maximim possible score = unlimited as measured subtotal on PCT, pretest.

Table 3
Wilks' Lambda Multivariate Test of Significance

Independent Variables	Wilks' Lambda	Approx. F	d.f	p
Instruction	0.87	2.30	4,62	0.069
School within Instruction	0.89	1.90	4,62	0.122
Grade	0.68	7.41	4,62	0.000*
Instruction by Grade	0.93	1.21	4,62	0.317
School by Grade	0.76	5.00	4,62	0.001
Gender	0.89	1.94	4,62	0.115
Instruction by Gender	0.09	1.54	4,62	0.203
School by Gender	0.88	2.17	4,62	0.083
Grade by Gender	0.87	2.40	4,62	0.060
Instruction by Grade by Gender	0.94	0.92	4,62	0.457
School by Grade by Gender	0.91	1.54	4,62	0.201

*$p < 0.001$

Table 4
Univariate F Test for Adjusted Invention Score

Independent Variables	F value	d.f.	p
Instruction	4.30	1,65	0.042
School within Instruction	0.44	1,65	0.508
Grade	1.50	1,65	0.226
Instruction by Grade	1.33	1,65	0.023
School by Grade	5.41	1,65	0.023
Gender	6.40	1,65	0.014
Instruction by Gender	2.99	1,65	0.089
School by Gender	0.47	1,65	0.497
Grade by Gender	0.22	1,65	0.639
Instruction by Grade by Gender	3.10	1,65	0.083
School by Grade by Gender	0.06	1,65	0.815

Table 5
Adjusted Mean Scores for Inventions
(Effect of Gender on Invention)

	Schools		
	Control	Experimental 1	Experimental 2
Female	35.13 (n=5)	60.17 (n=13)	59.75 (n=18)
Male	56.75 (n=15)	61.76 (n=19)	70.24 (n=14)

Table 6
Univariate F Test for Flexibility

Independent Variables	F value	d.f.	p
Instruction	0.81	1,65	0.371
Schools within Instruction	2.51	1,65	0.118
Grade	23.39	1,65	0.000*
Instruction by Grade	0.25	1,65	0.620
School by Grade	1.45	1,65	0.233
Gender	0.21	1,65	0.650
Instruction by Gender	0.32	1,65	0.573
School by Gender	6.27	1,65	0.015
Grade by Gender	2.85	1,65	0.096
Instruction by Grade by Gender	0.55	1,65	0.460
School by Grade by Gender	5.99	1,65	0.017

*$p < 0.001$

Table 7
Univariate F Test for Creativity

Independent Variables	F value	d.f.	p
Instruction	2.96	1,65	0.090
Schools within Instruction	4.02	1,65	0.049
Grade	20.58	1,65	0.000*
Instruction by Grade	0.66	1,65	0.420
School by Grade	5.97	1,65	0.017
Gender	0.02	1,65	0.879
Instruction by Gender	0.10	1,65	0.753
School by Gender	4.00	1,65	0.050
Grade by Gender	0.42	1,65	0.517
Instruction by Grade by Gender	0.90	1,65	0.348
School by Grade by Gender	4.01	1,65	0.049

*$p < 0.001$

Table 8
Univariate F Test for Attitude Towards Science

Independent Variables	F value	d.f.	p
Instruction	0.19	1,65	0.667
Schools within Instruction	3.62	1,65	0.061
Grade	0.00	1,65	0.987
Instruction by Grade	2.05	1,65	0.157
School by Grade	0.25	1,65	0.616
Gender	0.00	1,65	0.965
Instruction by Gender	2.91	1,65	0.093
School by Gender	2.65	1,65	0.108
Grade by Gender	2.13	1,65	0.150
Instruction by Grade by Gender	0.67	1,65	0.417
School by Grade by Gender	0.15	1,65	0.702