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ABSTRACT

This study investigated: (1) whether boys and girls master formal reasoning tasks to the same degree at the same age; (2) if the variance of boys' and girls' performance in formal tasks could be predicted by the same cognitive learning abilities; and (3) what are the main and interactional effects of age, sex, and school type on the variance of performance scores on formal reasoning tasks. Level of subjects' performance in formal tasks (subjects included 319 students from urban schools and 92 students from kibbutzim and small villages) was measured using a video-taped group test (VTGT) demonstration. The VTGT measured conservation and volume displacement, proportional reasoning, control of variables, combinatorial analysis, probabilistic reasoning, and correlational reasoning. Among the findings are those showing: that boys surpassed girls in VTGT performance in grades 7 through 11; that although the percentage of formal reasoners increased with age, half of the students in the total sample were in the concrete operational reasoning stage (this finding strengthens the universality of Piaget's cognitive development model); and a higher rate of cognitive development was found for kibbutzim students compared to urban students. Implications of these and other findings (including those related to spatial ability) for science instruction are addressed. (JN)

FORMAL REASONING SKILLS OF SECONDARY SCHOOL STUDENTS AS RELATED TO GENDER, AGE, SCHOOL TYPE AND LEARNING ABILITIES

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FORMAL REASONING SKILLS OF SECONDARY SCHOOL STUDENTS AS RELATED TO GENDER, AGE, SCHOOL TYPE AND LEARNING ABILITIES

Relationships between academic achievements in mathematics and sciences and formal operational reasoning were reported by Piburn (1980), Marek (1981) and Lawson (1982). Piaget and his colleagues defined the use of formal operational reasoning as the ending stage in the process of intellectual development. This process can be attributed to two factors:

1) Physical growth, especially maturation of the nervous system, which enables the individual to encode and process information more efficiently;

2) Exposure to the environment, which stimulates the development of mental constructs which, in turn, enables the individual to assimilate and accommodate new experience.

While age and gender are features of the first aspect, schooling, which includes type of school, subject matter, instructional method, classroom environment, etc., is one of the important factors of the second aspect.

There is a general agreement about the relations between age and intellectual development. As to the gender, the issue is still controversial. Significant sex related differences, generally in favor of boys, were found in Piagetian-like tests of logical operations, by Ross (1973), Graybill (1975), Schwebel (1975), Lawson (1975), How & Shayer (1981) and Hofstein & Mandler (1984). Such differences were not reported by Sarni (1973), De Luca (1979), Shayer (1979) and Kuhn et al (1977). Shayer (1984) suggested that the different results could evolve from methodological procedures such as small and/or unrepresentative samples, or from innate reasons, such as testing students from different age groups and interaction of age and task variables.

Studies of sex related differences in cognitive learning abilities such as mathematical, verbal and spatial abilities (Maccoby & Jacklin 1975; Fennema & Sherman 1977) give us a more definite picture. One can ask whether those cognitive abilities do contribute to the performance of boys and girls in formal reasoning tasks.

With relation to the second aspect of the int·llectual growth, Karplus et al (1977) found that type of school, learning materials taught, and instructional methods were in correlation with students' reasoning skills. Lawson (1984;b) found that differences in students' reasoning skills can be related to school type communities. In Israel, kibbutzim schools which differ from urban schools (Sharan & Yaakobi, 1981) offer unique school type communities and therefore can serve as a variable on testing students' reasoning skills in relation to their environment.

From the literature reviewed, it appears that there are some uncertainties about the relationships between the acquisition of formal reasoning skills and students' age, gender, cognitive learning abilities and school type environment. The main goal of this study was to investigate the possible existing relationships between students' level of performance in tasks which require the use of formal reasoning skills (Inhelder & Piaget, 1958) and the following independent variables: age, gender, cognitive learning abilities and school type (urban and kibbutzim). The study questions were:

(1) Do boys and girls master formal reasoning tasks to the same degree at the same age?

(2) Can the variance of boys and girls' performance in formal tasks be predicted by the same cognitive learning abilities?

(3) What are the main and interactional effects of the variables age, gender and school type on the variance of the performance scores on formal reasoning tasks, as were assessed in this stud.

Research Design

Sample: Three hundred and nineteen students from two urban schools (55% girls and 45% boys), with low and middle socio-economic backgrounds, and ninety-two students (54% girls and 46% boys) from kibbutzim and small villages (rural school) took part in this study, thus totalling N = 411 subjects. The distribution of the participating classrooms are presented in Table 2. All classes had an heterogeneous student population according to the definition of the Israeli Ministry of Culture and Education. Since the education system in Israel is highly centered, all the classes which took part in this research passed through a similar curriculum in science and mathematics, according to their grade level.

Research Instruments. The dependent variable in this study, the level of formal tasks performance was measured by a Video-Taped Group Test (VTGT) demonstration, which tested students' formal reasoning skills. This instrument was developed and validated in a former research (Shemesh and Lazarowitz, 1984) and is based mainly on Lawson's group demonstration test (Lawson, 1978). A similar technique was used by Tobin and Capie (1981) in which the use of the video-tape was found to be a convenient tool for presenting formal reasoning tasks. Staver and Pascarella (1984) had shown that method and format of Piagetian reasoning tasks had no effect on students' responses. These findings support the decision of selecting the VTGT as an objective instrument, via which the formal reasoning skills of secondary school students can be assessed.

The VTGT is composed of 12 video-taped demonstrations, which test the following skills of formal reasoning: (a) conservation and volume displacement; (b) proportional reasoning; (c) control of variables; (d) combinatorial analysis; (e) probabilistic reasoning; (f) correlational reasoning. The content of the majority of the tasks was from daily-life experience domain, to avoid interference of unfamiliar content, as was found by Lin, Clement & Pulus (1983). At the end of each video-taped demonstrations, students were asked to answer a multiple-choice questionnaire and to explain their choice. Schematic presentation of VTGT items are shown in Table 1.

INSERT TABLE 1 ABOUT HERE

Reliability and Validity. The VTGT reliability was obtained in a pilot study (Shemesh, 1983) with a sample of 300 secondary school students. This sample had a distribution of grades and gender as in the final study. The internal reliability obtained was α Cronbach = .83; and inter-judges' percentage of agreement on VTGT scoring was .93. Content validity of the test was assessed by a panel of 14 science educators and graduate students in the Science Education Department.

Scoring: for each correct answer and explanation, students received 2 points; for a wrong answer but a correct explanation - 1 point; zero points for the other two possibilities. Thus each student was eligible to receive a score from 0 to 24 points.

Cognitive Learning Abilities (CLA). Data were obtained from the Psychological Service which administered specific aptitude tests to all 9th grade students in Israel. These tests check verbal ability (vocabulary and understanding), mathematical ability (problems, forms and drills), spatial perception ability and hand-eye coordination ability (graphs and differentiations). The scores are in national percentiles norms. Since the CLA data were obtained only for 9th graders, only those students were considered for statistical analyses regarding cognitive learning abilities and VTGTs' achievement scores. Thus, concurrent validity for these measurement was maintained.

Procedure. All students were tested during the last two months of the 1983-1984 academic year in their classrooms, by one member of the research team while their teachers were present. The administration of the test lasted one classroom period. Students were informed that the test served only for research purposes and not for grading, thus avoiding any anxiety or tension.

Statistical Treatment and Results. Mean scores on VTGT of all graders clustered by school, grade and gender were analyzed by a t-test and are displayed on table 2.

INSERT TABLE 2 ABOUT HERE

The results indicate that boys surpassed girls in VTGT performance in all tested grades. The gap between boys and girls seem to increase with age. While in 7th and 8th grades in urban and kibbutzim schools, boys means scores were slightly higher than those of the girls, significant differences were found in both types of schools in higher grades, namely 9th, 10th and 11th grades.

In order to find out whether or not differences on VTGT mean scores are related to different cognitive development rate of boys and girls, students were categorized into three clusters by their scores: (a) concrete reasoning level (zero to 8 points); (b) transitional level (9 to 16 points); and (c) formal reasoning level (17 to 24 points). The percentage of students in each level was calculated over school type variable for each grade, by gender, and are presented in histogram 1.

<u>INSERT HISTOGRAM 1 ABOUT HERE</u>

From Histogram 1 it can be clearly concluded that (1) boys show formal reasoning patterns earlier than girls, and (2) in any grade level the percentage of boys who can be considered by VTGT performance as formal reasoners is higher than that of girls.

In searching for an explanation of gender-related differences, on VTGT performance, it was decided to investigate the relationship between cognitive learning abilities (CLA) and students achievements on formal reasoning tasks. Two groups were formed for this purpose (25 boys and 25 girls). Students in each group were selected so as to form matched means between the groups in the four variables that CLA is consisted of: verbal, numerical, spatial and hand-eye coordination abilities. Findings are displayed in table 3.

<u>INSERT TABLE 3 ABOUT HERE</u>

It can be seen that the means of both groups on numerical ability and hand-eye coordination are almost identical. In the other two variables, girls mean scores on verbal ability are slightly higher, while boys spatial ability scores are higher than those of the girls. The correlation matrix of the VTGT and CLA scores of boys and girls is presented in Table 4.

<u>INSERT TABLE 4 ABOUT HERE</u>

Summaries of the multiple linear regression for the same data are displayed on table 5 for the boys and girls.

<u>INSERT TABLE 5 ABOUT HERE</u>

From the above table it can be seen that while numerical and spatial abilities are significant predictors of boys' level of performance on VTGT, girls' performance can be best predicted by numerical and verbal abilities.

Findings on table 2 have shown that differences on VTGT mean scores were not related only to age and gender but to school type too. In order to find out the relative effect of school, grade and gender, a three-way analysis of variance was carried out. The results are presented on table 6.

INSERT TABLE 6 ABOUT HERE

The results indicate that age and gender have significant effects on students performance of the VTGT tasks. The interaction between age and gender, and age and school were found also to be significant.

DISCUSSION

Lin and Levine (1978) and Wollman (1982) called the attention of researchers and science educators to the problem of the generalizability of the results of group assessment of cognitive development. In order to avoid further discussion of this issue, the phrase "level of cognitive development" or "formal reasoning level", used in this study, represents only the level of performance on VTGT tasks. Although in a previous study (Shemesh and Lazarowitz, 1984) VTGT was found to be a valid measure of formal reasoning skills, in our opinion it is still a limited test, which can assess only specific features of adolescence reasoning patterns.

The findings of this study show that the percentages of formal reasoners increased with age, but still half of the students in the total sample were in the concrete operational reasoning level. Similar findings were reported by Shayer et al (1976), who found that only 7% of 14 year old students, in England, reached the formal operational stage. The percentages of Israeli 8th grade students (14 year olds) who can be considered as formal reasoners, was almost the same, 9%. In a research which compared the acquisition of propositional logic and formal operational schemata, during secondary school years, Lawson et al (1978) found that the percentages of students who responded correctly to Piagetian-like tasks, increased from 10% with 11 year old students, to 75% with 20 year olds. This similarity in the process of cognitive development, among British, American and Israeli students, strengthens the universality of Piaget's cognitive development model.

Generally there is a vast concensus about the association of intellectual development to age, but the specific role of the various factors which can be responsible to this development is not so clear. One possible way to look at this issue is to compare students from different school types with their cognitive reasoning level. In this study, it was found that school type community did contribute to the variance on VTGT performance. While no differences were found between the two urban schools' students, differences were found between the kibbutzim school students (N=92) and urban school students (N=173); the values of t=2.83, P < .01; t=1.92, P < .05; t=1.82, P < .05; t=1.44, P < .07; were found for grades 7th, 8th, 9th and 10th respectively.

There are two possible explanations for the higher rate of development of the kibbutzim students: (a) Kibbutzim students are offered a more informal education and extra-curricular activities than urban school students. (b) In the kibbutzim elementary schools, students are more autonomous, since they experienced new instructional methods, such as hands-on activities, learning centers, individual projects and social interactions. Some of these activities were found to promote student cognitive development, as was found by Cohen (1984).

While the schools' effect on cognitive development was found to be low, sex effect was found to be highly significant. Boys' superiority in performance of formal tasks was found also by Marek (1981), Hofstein and Mandler (1982), and Hernandez (1984). De Luca (1981) claims that there is no theoretical basis for these gender-related differences. Based on Inhelder and Piaget protocalls (1958), De Luca concluded that Piaget formulated his stage theory mainly on the ground of boys' responses. Therefore, one can assume that Piagetian-like instruments for assessing cognitive development are biased in favor of boys.

From our findings, especially those of the regression of VTGT scores on students' cognitive learning abilities (table 5), it seems that there is a possible explanation for the gap between the performance of boys and girls. The VTGT is based on students' visualization and perception of the demonstration, which serves as cues for answering the test items. Visualization and perception are important components of spatial ability. Therefore, boys can benefit from their better spatial perception ability, while performing the VTGT tasks.

Two main approaches can be found in the literature of sex-related differences: The first approach perceives the development of sex-type activities and interests, during adolescence, as the origin for the emerged differences (Harris, 1978; Nash, 1975; Newcomb, 1983); the second approach trys to explain the differences on the ground of maturation processes, brain lateralization, and even in genetic factors (Levy, 1974; Waber, 1976, 1977). Whatever the factors may be, they influence not only spatial perception, but other cognitive processes as well. The issue of the relationship among gender, formal reasoning and spatial perception deserve detailed investigation.

Are there any relationships among formal reasoning skills, gender and science-lessons attendance? Lawson and Bealer (1984;a) found differences between formal and concrete reasoners, in respect to their science learning choices. In addition, Lazarowitz and Hertz-Lazarowitz (1979) reported about gender-related preferences of science subject matter by junior high school students. Can the level of formal reasoning be the cause of gender-related differences in course selection by high school students? In this study, the issue was treated by asking students to name their two favorite school subjects. Among 9th graders, for example, the majority of the boys preferred mathematics and technology, while the majority of the girls preferred arts and humanities.

Can the differences in cognitive development found in this study, be the source of boys' and girls' preferences of subject-matters? If so, then the formal operational level of students should be considered by science curricula developers and science teachers, in two ways. One way is to postpone the instruction of formal concepts and principles to the higher grades of the high school. The other way is to integrate the teaching of formal concepts and principles with specific training, aimed at developing formal reasoning skills.

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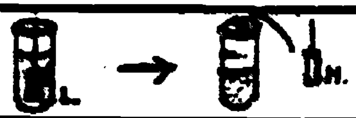
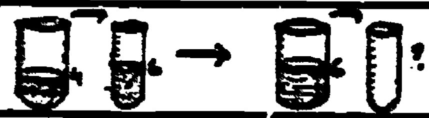
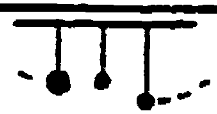
TABLE 1

SCHEMATIC DESCRIPTION OF VTGT ITEMS

ITEM NAME	REASONING SKILL	DESCRIPTION OF DEMONSTRATION	ORIGIN*
1. Balls of Clay	Conservation of Weight		Piaget & Inhelder (1962)-a
2. Weights	Volume Displacement		Karplus & Lavatelli (1969)-a
3. Cylinders	Proportional Reasoning		Suarez & Rhonheimer (1974)-a
4. Cylinders	Proportional Reasoning		Suarez & Rhonheimer (1974)-a
5. The Pendulum	Control of Variables		Inhelder & Piaget (1958)-a
6. On the Ramp	Control of Variables		Wollman (1977)-a
7. Squares	Probabilistic Reasoning	 (2:6)	Lawson (1978)-b
8. Squares & Rhombuses	Probabilistic Reasoning	 (9:18)	Lawson (1978)-b
9. Foods	Combinatoric Reasoning		c
10. Stores	Combinatoric Reasoning		Lawson (1978)-b
11. Striped Fish	Correlational Reasoning		Lawson, Karplus & Ady (1978)-b
12. Coloured Flowers	Correlational Reasoning		c

* a = adapted from Lawson test without modifications.
b = adapted from Lawson test with modifications.
c = original item.

TABLE 2

T-TEST COMPARISONS OF VTGT MEAN SCORES AND DESCRIPTIVE DATA OF THE SAMPLE

		Boys			Girls			
School	Grade	N	Means	SD	N	Means	SD	t
Urban I	7	23	7.65	4.01	14	7.02	2.89	0.51 n.s.
Urban I	8	15	9.80	5.67	15	9.33	3.11	0.28 n.s.
Urban I	9	14	13.36	5.47	20	10.50	4.33	1.80 *
Urban I	10	17	15.92	4.89	18	11.60	4.58	2.70 **
Urban I	11	12	16.66	2.96	25	13.87	5.06	1.78 *
Urban II	9	42	13.2[illegible]	5.39	33	10.63	4.60	2.40 **
Urban II	10	22	15.95	5.01	49	12.20	4.66	3.06 **
Kibbutzim	7	13	10.54	5.31	13	9.84	3.43	0.40 n.s.
Kibbutzim	8	12	13.33	5.19	11	10.27	3.82	1.60 n.s.
Kibbutzim	9	10	14.71	3.39	14	13.35	6.09	0.64 n.s.
Kibbutzim	10	8	18.37	2.66	11	13.45	4.97	3.64 **

* $p < .05$
** $p < .01$

HISTOGRAM 1

DISTRIBUTION OF STUDENTS ACCORDING
TO COGNITIVE LEVELS IN PERCENTAGE
BY GRADES AND GENDER

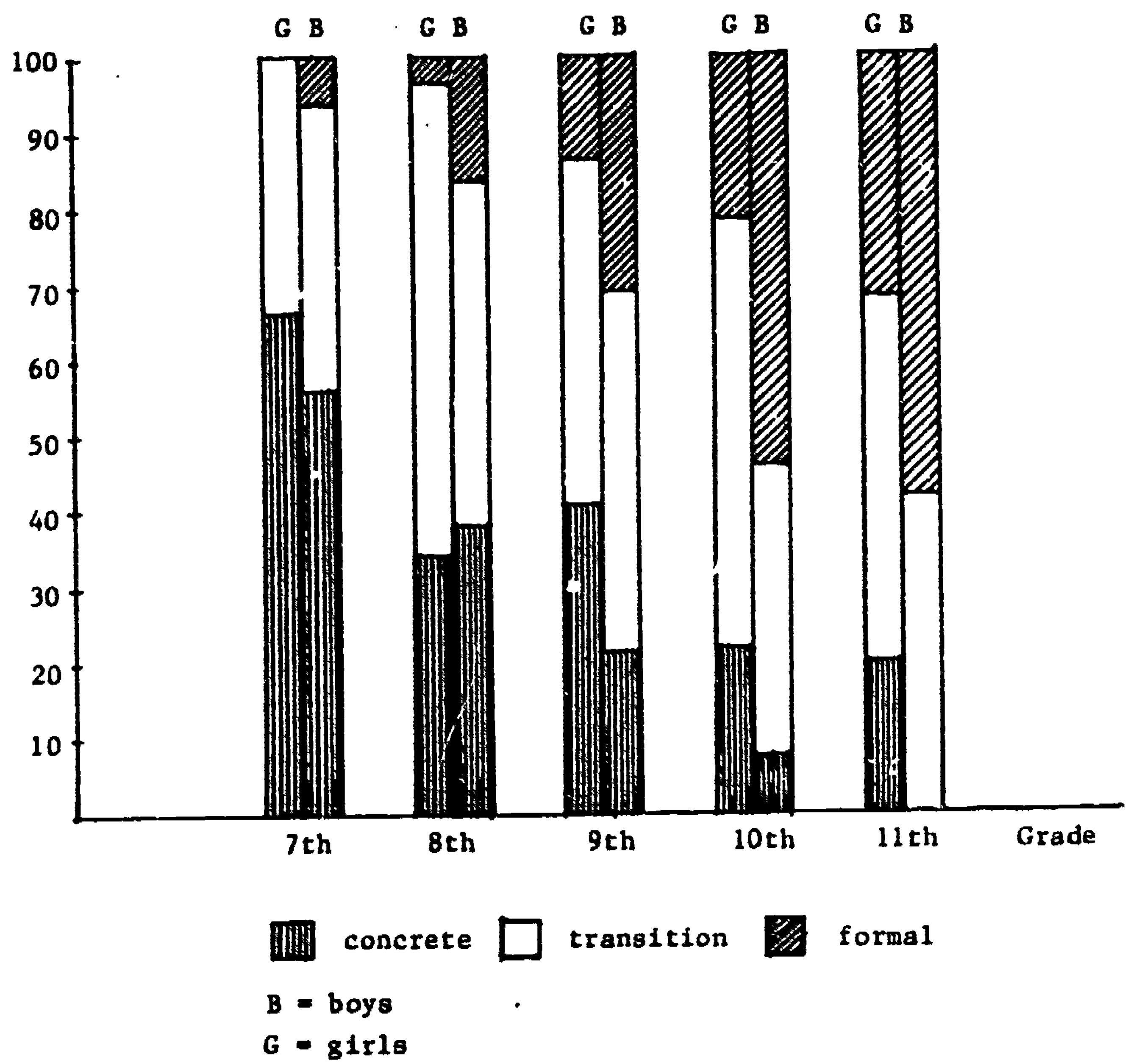


TABLE 3

MEANS AND STANDARD DEVIATIONS
OF CLA BY GENDER

	Boys (N=25)		Girls (N=25)			
Variable*	Mean	SD	Mean	SD	t	p
VTGT	13.12	5.21	12.6	4.98	0.36	0.35
VER	6.09	1.31	6.61	0.99	1.58	0.06
NUM	5.86	1.03	5.84	0.93	0.07	0.47
SPA	6.12	1.08	5.80	1.34	0.93	0.18
HAND	5.82	1.71	5.76	1.96	0.12	0.45

* VTGT: Video-taped group test

VER : Verbal ability

NUM : Numerical ability

SPA : Spatial perception ability

HAND: Hand-eye coordination ability

TABLE 4

CORRELATION MATRIX OF VTGT SCORES AND CLA SCORES
OF 9TH GRADE BOYS (N=25) AND GIRLS (N=25)

	VTGT		VER		NUM		SPA	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
VER	0.66*	0.51*						
NUM	0.70*	0.51*	0.74*	0.43*				
SPA	0.57*	0.29	0.49*	0.57*	0.43*	0.48*		
HAND	0.20	0.12	0.29	0.28	0.42*	0.13	0.26	0.70*

* $P < 0.05$

TABLE 5

SUMMARY OF MULTIPLE REGRESSION
OF VTGT SCORES ON CLA SCORES

BOYS:

Variable	cum R^2	B	SD error B	F
NUM	0.487	2.38	1.10	4.6 **
SPA	0.575	1.43	0.77	3.38 *
VER	0.596	0.84	0.85	0.96
HAND	0.610	-0.4	0.47	0.75

($N = 25$; $F_{4,20} = 7.85$)

GIRLS:

Variable	cum R^2	B	SD error B	F
NUM	0.264	2.60	1.11	5.49**
VER	0.368	2.46	1.07	5.27*
SPA	0.402	-1.66	1.17	2.017
HAND	0.427	0.60	0.65	0.846

($N = 25$; $F_{4,20} = 3.73$)

* $P < 0.05$
** $P < 0.01$

TABLE 6

THREE-WAY ANALYSIS OF VARIANCE OF VTGT SCORES
BY SCHOOL, GRADE, GENDER AND THEIR
INTERACTIONS

Source	DF	MS	F
Model	17	202.44	9.32 **
Error	397		
School	2	87.47	4.49 *
Grade	4	490.09	22.57 **
Sex	1	469.74	21.64 **
School X Grade	4	82.98	3.82 n.s.
School X Sex	2	7.87	0.36 n.s.
Grade X Sex	4	117.19	5.40 **

* $P < .05$
** $P < .01$