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ABSTRACT

The National Assessment of Educational Progress (NAEP) serves as the nation's primary indicator of what school children know and can do. This study examines the policy relevant variable, computer use in the classroom, as indicated by the 1992 NAEP Trial State Assessment data for Mississippi. After a preliminary examination of other variables relevant to educational policy, a hierarchical linear model analysis was performed for the composite mathematics score within the eighth grade in Mississippi. Gender, race-ethnicity, and socioeconomic differences in scores were identified, and their correlation with school and student variables was explored. In Mississippi, 53% of students did not have computers available in their classrooms. While neither availability/access nor frequency of computer use was found to be statistically significantly associated with average school achievement, both variables showed associations with the gap between minority and nonminority students. In schools where computers were the most available and accessible, the gap between minority and nonminority students was significantly reduced. Implications of these findings for educational policy are provocative. (Contains 6 tables, 9 figures, and 18 references.) (SLD)

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Running Head: COMPUTERS AND MATHEMATICS ACHIEVEMENT

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An Analysis of NAEP Trial State Assessment Data Concerning the  
Effects of Computers on Mathematics Achievement

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## Abstract

Recent emphasis has been made on improving education through educational reform. The National Assessment of Educational Progress (NAEP) has played an increased role in measuring student achievement, especially at the state level. It serves as the Nation's primary indicator of what school children know and can do and has become "The Nation's Report Card". NAEP data is a rich source of information awaiting analysis. It has the potential of providing tremendous insights to policy makers and educational planners. However, due to its complexity, few researchers have attempted to analyze the data for specific policy implication.

This study will provide an examination of the policy relevant variable, computer use in the classroom, contained in the 1992 National Assessment of Educational Progress Trial State Assessment (NAEP-TSA) data for Mississippi. It will address the potential relationship between computers in the classroom and student mathematics performance.

Computers can be used in a wide variety of ways in mathematics classrooms. Although they may be most frequently used for computational drill and practice, teachers can take full advantage of this technology by using computers to teach graphs, spreadsheets, and extended investigations of mathematical ideas. The computer has the potential to provide opportunities for problem solving using "hands-on" techniques and also can be effective as a tool in small group. This study will use information from students and teachers included in the NAEP-TSA sample to construct variables to assess computer use and availability and measure the relationship between these variables and mathematics performance.

Educational researchers have been studying "school effects" for quite sometime. In such studies the researcher seeks to identify characteristics in schools that are associated with student outcomes, separate from the characteristics of the students themselves. Thus, the purpose is to understand why some schools seem to be better able to produce positive educational outcomes than other schools. A major concern in studying school effects has been to take into account and measure accurately the factors at all levels that could influence achievement.

Following a preliminary examination of policy-relevant variables, a hierarchical linear model (HLM) analysis will be performed for the composite mathematics score within eighth grade in Mississippi. In addition, gender, race-ethnicity, and socioeconomic status differences in these scores will be identified and their correlation with school and student variables will be explored.

The variables from the NAEP/TSA data to be used in the analysis are: (1) Student-level Variables: gender, race/ethnicity or minority/non-minority, socioeconomic status; (2) School-level Variables (Instructional characteristics of the school): computer use in the classroom and availability/access of computers.

The results of this study will address a very important policy question about the association between the use and availability of computers in the classroom and student proficiency. The conclusions can readily impact institutional policy and instructional changes at the local and state policy levels. The secondary analysis of NAEP data, along with the use of HLM, holds promise of providing educational practitioners and policy makers with rich information about possible school and classroom influences.

## Introduction

This paper is a part of a project funded by a grant received from the U.S. Department of Education, National Center for Education Statistics (R999850010). This paper reports on only one of the components funded by the grant. It will analyze and report on the data from the 1992 National Assessment of Educational Progress Trial State Assessment (NAEP-TSA) in Mississippi. The primary purpose of this study is to develop a model for analyzing state data that researchers in state agencies will find useful. It uses state-of-the-art hierarchical linear modeling (HLM) statistical procedures to investigate policy-relevant instructional variables that impact on students' mathematics performance. The results can be used to provide educational policy makers and planners with information for the improvement of educational programs and practices.

With national emphasis on improving education, NAEP has played an increased role in measuring student achievement. With the assistance of NAEP and the "National Report Card," Americans may identify states in need of improvement. However, just a ranking of states is not very useful. What is needed is useful information to impact policy. Most of the states in the nation have implemented State Report Cards as a measure of accountability and student achievement to provide the public and policy makers with comparable information on the progress of state education programs. However, states do not make adequate use of NAEP data. While NAEP data is a rich source of information awaiting analysis, few researchers have attempted to analyze the data for specific policy implication. Since the National Educational Goals Panel is establishing ways to report NAEP data, this project will provide a model for using NAEP-TSA analyses on student achievement as a part of state report cards.

A review of the results from the 1992 NAEP data confirms what many already believed, that students in the southeastern region of the U. S. are substantially behind the rest of the nation in mathematics achievement. Nationally, students in grade four had an average mathematics proficiency of 217 while students in the southeast had an average of 209. A similar pattern is seen for students in grade eight, 268 nationally and 258 for the southeast. Further, two percent of the nations' fourth grade students and three percent of the eighth grade students performed above average in mathematics achievement while only one percent performed above average in the southeast. The nation as a whole had 39 percent of the eighth grade students performing below basic proficiency while the southeastern region had 47 percent. In the fourth grade the gap is even wider - 41 percent for the nation and 52 percent for the southeast. With such a deficit, this team of researchers challenged each other to develop a model for using NAEP-TSA data to identify policy-relevant variables that could lead to improving mathematics achievement in the southeastern states.

In short, students in the southeastern region of the U.S. are performing below the nation as a whole and students in Louisiana, Mississippi, and North Carolina are scoring among the lowest in the southeast. As educational planners and policy makers continue to strive to improve education in these states, information from the NAEP data should be utilized. Information from the NAEP-TSA data can provide information for decision makers when considering such questions as:

1. Should education policy makers expect to see mathematics achievement improve if they significantly increase technology funds for computers in classrooms?
2. Would scarce educational funds be better spent helping teachers understand new methods of delivering mathematics instruction?

3. Should states and local school districts develop policies that would encourage students and parents to spend more time on homework?

NAEP-TSA provides us with the data and HLM statistical techniques provide us with the method to examine policy-relevant activities and practices. While factors appear to be related to eighth grade public school students' proficiency in mathematics, cause-and-effect links between various contextual factors and students' mathematics proficiency may not be established.

However, this paper is designed to reveal promising policy implications about the relationship between computer use and/or availability, various student body characteristics, and mathematics performance.

#### Using NAEP Data for Studying Instructional Policy

As educational planners and policy makers continue to strive to improve education, this team of researchers believes that information from the NAEP-TSA data should be utilized. This paper focuses on a set of policy questions that address, "how students' mathematics performance is influenced by the availability and use of computers." This relationship has implications for policy makers at three different levels: (a) classroom, (b) school, (c) and state.

Educational researchers have been studying "school effects" for a long time. (See Brookover, Beady, Flood, Schweitzer, and Wisenbaker (1979), Rutter (1983), Good and Brophy (1986), Good and Weinstein (1986), Weinstein (1986), Oakes (1989), Arnold, Kaufman and Sedlacek (1992), and Sedlacek (1991). In such studies the researcher seeks to identify characteristics in schools that are associated with student outcomes, separate from the characteristics of the students themselves. Thus, the purpose is to understand why some schools seem to be better able to produce positive educational outcomes than other schools. A major

concern in studying school effects has been to take into account and measure accurately the factors at all levels that could influence achievement (Burstein, 1980).

The practices and policies at the local school level have a direct influence on student achievement. Local schools influence instruction through such policies as student access to computers by providing computer laboratories, classroom computers, computer take-home policies, etc. Local school boards make policies that impact mathematics instruction and student achievement when they make resource allocation decisions that effect instruction such as student/computer ratio and student access to computers. State policy makers can also have a positive impact on school practices through programs that encourage and provide adequate access to computer usage, instructional methodology, and instructional practices. This study will provide information from which policy recommendations can be made to improve mathematics performance.

### Theoretical Framework

This project takes its lead from the landmark action of the National Council of Teachers of Mathematics (NCTM) which set standards for mathematics curriculum and teaching. According to NCTM, all students must learn more mathematics, and sometimes, different mathematics to improve this mathematics proficiency. Mathematics instruction has been characterized by extensive use of textbooks and worksheets (Romberg and Carpenter, 1980). What students learn depends, to a great degree, on how the instruction has been presented to them. According to NCTM, classroom instruction needs to be more student centered (NCTM, 1989).

NCTM recommends well-equipped classrooms and instruction reflecting the vitality of mathematics. They also recommended the use of small groups and cooperative-learning strategies for mathematics teaching. Educators argue that teaching must move away from a computation-dominated curriculum to a curriculum that stresses problem solving and understanding (Taylor, 1990). Small group instruction is appropriate for this type of curriculum. Further, this approach mirrors the use of mathematics in the workplace and reduces mathematics anxiety (Mullis et al., 1991).

NCTM standards recommend that schools take a look at how teachers are providing mathematics instruction. Results of a survey of elementary teachers indicate that: (a) most teachers use few materials other than textbooks in mathematics instruction, (b) use of most materials tends to decrease as grade level increases, (c) calculators are rarely used, but usage tends to increase with grade level, and (d) most teachers report they want more materials (Scott, 1993).

A central purpose of this study is to describe a set of policy-relevant variables associated with student mathematics achievement. Specifically, access and use of computers to improve mathematics performance of eighth grade students has relevant policy implication for both local and state policy makers.

#### Purpose of Study

NAEP has played an increased role in measuring student achievement, especially at the state level. It serves as the Nation's primary indicator of what school children know and can do and has become "The Nation's Report Card". NAEP data is a rich source of information awaiting detailed analysis. It has the potential of providing tremendous insights to policy makers and



educational planners. However, due to its complexity, few researchers have attempted to analyze the data for specific state and local policy implications. This study will provide a preliminary examination of policy relevant variables of interest contained in the 1992 NAEP-TSA data in Mississippi. It addresses the potential relationship between policy-relevant instructional practices and student mathematics performance of eighth grade students attending public schools.

In the NAEP data, the students' mathematics teachers stated that more than 50% of eighth graders, nationwide, have never or hardly ever used a computer in mathematics classes. In the southeast, this rate was 62%. In Mississippi, 80% of the teachers reported that they never, or hardly ever, used a computer.

Only 18% of the students reported using a computer at least once a week and 52 percent reported that they never used a computer in class. From the students' perspective, 50 percent of the fourth graders, 69% of the eighth graders, and 66% of the twelfth graders taking mathematics reported never using a computer in mathematics class. (NCES, 1991)

For the states participating in the 1992 Trial State Assessment, teachers reported low availability of computers in public-school eighth-grade mathematics classrooms. For the nation as a whole, twenty-four percent of the eighth graders had teachers who reported that computers were not available. In the southeast, twenty-nine percent of the eighth graders had teachers who reported not having computers available. For Mississippi, this number jumps to fifty-three percent.

A major goal of this study is to identify policy-relevant variables that have an impact on student academic performance. One such variable that policy makers can have influence over is how computers are used in education. Computers can be used in a wide variety of ways in

mathematics instruction. Computers are frequently used for computational drill and practice, however, teachers can take full advantage of this technology by using computers to teach graphs, spreadsheets, and extended investigations of mathematical ideas. The computer has the potential to provide opportunities for problem solving using "hands-on" techniques and can be an effective tool in a small group (Male, 1990). This study uses information from students and teachers included in the NAEP-TSA data to construct measures of computer use and availability and identify relationships between these variables and mathematics performance.

#### Computer Availability/Access and Use

Recommendations for improving mathematics education often include more use of computers. The NCTM has proclaimed the benefits of computers by stating that (a) A computer should be available in every classroom for demonstration purposes, and (b) every student should have access to a computer for individual and group work (NCTM, 1991).

NCTM suggests that computers, along with calculators, provide a basis for more complex problem-solving situations that engage students in mathematics learning. Incorporating computers as integral parts of classroom instruction can help make school mathematics become more like the mathematics people actually use in their everyday lives and on the job. The availability of increasingly sophisticated and economically feasible technology, such as computers, can be used to accelerate the pace of student learning in mathematics (NCTM, 1991).

Included in the NAEP-TSA data are responses from a questionnaire given to both school administrators and teachers about the availability of computers in mathematics classrooms. Administrators were asked if computers were available all the time in mathematics classrooms; if computers were grouped in a laboratory available to mathematics classes; and if computers

were available to bring to the classroom when needed. Teachers and students were asked about the frequency of computer use. Teachers were asked about how often their students use computers in their classes. Students were asked, "In mathematics class, how often do you do the following? - Use a computer at least once a week; less than once a week; never." Teachers were also asked to estimate the time that students spend each week working with computers to solve mathematics problems - none; 15 minutes; 30 minutes.

#### Policy-Relevant Issues To Be Investigated

1. Do schools with greater availability/access to computers have higher achievement levels?
2. Do schools where students use computers more frequently have higher achievement levels?
3. Do schools with greater availability/access to computers have a smaller gap between minority students and nonminority students?
4. Do schools where students use a computer more frequently have a smaller gap in achievement between minority students and nonminority students?
5. Do schools with greater availability/access to computers have a smaller gap in achievement between female and male students?
6. Do schools where students use a computer more frequently have a smaller gap in achievement between female and male students?
7. Do schools with greater availability/access to computers have more or less of a difference in achievement between high and low SES students?
8. Do schools where students use a computer more frequently have more or less of a difference in achievement between high and low SES students?

### Method

This study investigates data in the NAEP-TSA to determine if the data would support a relatively new statistical method called “hierarchical linear modeling” (HLM) (Bryk and Raudenbush, 1992). This method of analysis offers several advantages. First, one can explain student achievement as a function of school level characteristics while taking into account the variance of student outcomes within the school. Second, one can model the effects of student characteristics, such as gender, race-ethnicity, and socioeconomic status, on achievement within schools. This allows for the explanation of differences in the effects between schools serving students with different characteristics. A third advantage is that one can model the between and within-school variance at the same time, thus producing more accurate estimates of student outcomes. Finally, one can derive better estimates of the predictors of student outcomes within schools and classrooms by “borrowing” information about these relationships from other schools and classrooms.

This paper includes the examination of the policy relevant variables of interest to be used in the development of linear models that seek to explain variation in mathematics achievement scores, using both classroom level and school level variables as explanatory variables. Additionally, instructional characteristics will be obtained by aggregating information from teacher data to the school level for grade analysis. HLM allows the prediction of student level outcomes as a function of school factors, while controlling for student level factors. Thus, the multi-level nature of the data can be modeled. HLM also provides for the identification of differences by gender, race-ethnicity and socioeconomic status in the correlation of school level factors with achievement.

The variables from the NAEP-TSA data to be used in the analysis are: (a) Student-level Variables: gender, race/ethnicity or minority/nonminority, socioeconomic status; (b) School-level Variables (Control Variables): percentage of student body that is minority/nonminority, percentage of females in the student body, and average socioeconomic level of the student body; and (c) School-level Variables: computer availability and use.

#### Variables Used in the Model

##### Student level variables

The student level variables for the eighth grade sample in the state of Mississippi were based on 2,498 original cases. The following level 1 variables were included in this study:

DRACE	derived race of student (recoded into 0 = nonminority, 1 = minority)
DSEX	derived sex of student (0 = male, 1 = female)
SES	composite of 6 variables related to parents' education and home environment
B007501A	frequency of computer use for schoolwork

##### School level variables

The school level variables were based on 93 cases in the state of Mississippi. The following school level variables were included in this study:

MDRACE	proportion of minorities in student body (average of DRACE)
MDSEX	proportion of females in student body (average of DSEX)
MSES	average SES level of student body
MCUSE	average frequency of computer use
COMPAVAL	computer availability/access

The computer availability/access variable was created using three school level variables and one teacher response. The following three school level variables were chosen because they to relate to computer availability in a classroom:

- C029301      Are computers always available in math classrooms?  
 C029302      Are computers grouped in a lab for math classes?  
 C029303      Are computers available to bring to math classes?

In order to categorize schools, the following ordered triples of the form (C029301, C029302, C029303) were generated with 1 indicating a 'yes' response to the corresponding variable:

(0,0,0)	(1,0,0)	(0,1,0)	(1,1,0)
(0,0,1)	(1,0,1)	(0,1,1)	(1,1,1)

The next step was to utilize the teachers' response to question T045201 - Are computers available for your class? This variable consisted of the following three responses: (a) not available, (b) difficult, and (c) available. The school categories were cross tabulated with the teacher response to determine the proportion of teachers in each school category who said that computers were either difficult or available. The final computer availability/access variable represents the proportion of teachers in each category of school who indicated that computers who accessible. See Table 1.

Table 1

Final values of computer availability/access variable

School Level Computer Availability			Final Computer Availability/Access
C029301	C029302	C029303	
0	0	0	26.83
0	0	1	48.94
0	1	0	59.65
1	0	0	71.48
0	1	1	73.30
1	1	0	100
1	0	1	N/A
1	1	1	N/A

## HLM Specifications

Let  $y_{ij}$ ,  $DRACE_{ij}$ ,  $DSEX_{ij}$ ,  $SES_{ij}$ , and  $CUSE_{ij}$  be the plausible mathematics achievement score, derived race, derived sex, socioeconomic status, and computer use of the  $i$ th student in the  $j$ th school, respectively. For the intercept to be interpreted as the average achievement of a given school, student level predictors were centered. Now let  $MDRACE_j$ ,  $MDSEX_j$ ,  $MSES_j$ , and  $MCUSE_j$  be average values of the derived race, derived sex, socioeconomic status, and computer use of the  $j$ th school. Respectively. Since derived race and derived sex are dichotomous variables,  $MDRACE_j$  and  $MDSEX_j$  can be viewed as the proportion of minority and proportion of females in the sample of students selected from the  $j$ th school. Further,  $MSES_j$  and  $MCUSE_j$  can be used as school level SES and computer use measures. Now, the centered student level

predictor variable for the  $i$ th student in the  $j$ th school can be given as  $CRACE_{ij} = DRACE_{ij} - MDRACE_j$ ,  $CSEX_{ij} = DSEX_{ij} - MDSEX_j$ ,  $CSES_{ij} = SES_{ij} - MSES_j$ , and  $CCUSE_{ij} = CUSE_{ij} - MCUSE_j$ .

Subject to the notation introduced above, the following HLM models at the student level (LEVEL-1) and at the school level (LEVEL-2) were hypothesized.

#### LEVEL-1 MODEL

$$y_{ij} = \beta_{0,j} + \beta_{\text{race},j} CRACE_{ij} + \beta_{\text{sex},j} CSEX_{ij} + \beta_{\text{ses},j} CSES_{ij} + \beta_{\text{cuse},j} CCUSE_{ij} + \epsilon_{ij}$$

for  $j = 1, \dots, k$  and  $i = 1, \dots, n_j$  where  $k$  is the number of schools sampled and  $n_j$  is the number of students sampled from school  $j$ .

In the LEVEL-1 model,  $\beta_{0,j}$  can be viewed as the average school achievement of the  $j$ th school. Since the predictor variables have been dichotomized,  $\beta_{\text{race},j}$  and  $\beta_{\text{sex},j}$  can be viewed as the race and gender gaps for the  $j$ th school. In the LEVEL-1 model, it is assumed that, conditionally,  $\epsilon_{ij} \sim \text{i.i.d.}N(0, \sigma^2)$ . (i.e. Conditioned on the random beta parameters, achievement scores within a school are assumed to be independently, identically, and normally distributed with mean zero and variance  $\sigma^2$ ).

#### LEVEL-2 MODELS

At the school level, relationships between the race and gender gaps, and SES and computer use slopes and the computer availability measures described earlier were studied. In addition, the effects of the proportion of minority, proportion of females, average SES, and



average computer use at the school level on the race and gender gaps as well as the SES and computer use slopes were of interest.

$$\text{Let } \beta_0 = \begin{pmatrix} \beta_{0j} \\ \beta_{racej} \\ \beta_{sexj} \\ \beta_{sesj} \\ \beta_{cusej} \end{pmatrix} \quad \Gamma = \begin{pmatrix} \gamma_{0,0} & \gamma_{0,a} & \gamma_{0,r} & \gamma_{0,x} & \gamma_{0,s} & \gamma_{0,c} \\ \gamma_{r,0} & \gamma_{r,a} & \gamma_{r,r} & \gamma_{r,x} & \gamma_{r,s} & \gamma_{r,c} \\ \gamma_{x,0} & \gamma_{x,a} & \gamma_{x,r} & \gamma_{x,x} & \gamma_{x,s} & \gamma_{x,c} \\ \gamma_{s,0} & \gamma_{s,a} & \gamma_{s,r} & \gamma_{s,x} & \gamma_{s,s} & \gamma_{s,c} \\ \gamma_{c,0} & \gamma_{c,a} & \gamma_{c,r} & \gamma_{c,x} & \gamma_{c,s} & \gamma_{c,c} \end{pmatrix}$$

$$W_j = \begin{pmatrix} 1 \\ AVAL_j \\ MDRACE_j \\ MDSEX_j \\ MSES_j \\ MCUSE_j \end{pmatrix} \quad \text{and} \quad U_j = \begin{pmatrix} U_{0j} \\ U_{racej} \\ U_{sexj} \\ U_{sesj} \\ U_{cusej} \end{pmatrix}$$

Then, at LEVEL-2, we hypothesized

$$\beta_j = \Gamma W_j + U_j \quad \text{for } j = 1, \dots, k \text{ for the "gap" and "slope" analyses.}$$

In the LEVEL-2 models above, it is assumed that  $U_j \sim \text{i.i.d.MVN}_5(0, \tau)$  for  $j = 1, \dots, k$ .

That is, the variance covariance matrices are assumed to be equal across schools. (Empirically, in our analyses, this assumption does not appear to hold true.)

## HLMPV Software

NAEP provides five plausible mathematics achievement scores for each student. Five HLM analyses need to be conducted and the results combined according to the method described in the NAEP technical report. The HLMPV software which was used to conduct the analyses provided the following results.

1. Generalized least squares estimators of regressor parameters in level-2 models (i.e.  $\gamma$ -parameters), their standard errors, and associated t-test statistics for testing  $H_0: \gamma_{ij} = 0$  versus  $H_1: \gamma_{ij} \neq 0$ .
2. Maximum likelihood estimators of the variance component estimators,  $\tau_{qq}$ 's. (i.e. qth diagonal elements of  $\tau$ ) and the associated chi-square test for testing  $H_0: \tau_{qq} = 0$  versus  $H_1: \tau_{qq} > 0$ .
3. Average reliability measure for each randomly varying regressor parameter in the LEVEL-1 model. The variability of the estimate of a LEVEL-1 random regressor parameter consists a component due to the sampling error and a component due to the variability of the parameter itself. Average reliability measures are, in general, the proportion of the variability of parameter estimates that can be attributed to the parameter variability.

## Cautions When Using HLM

When analyzing NAEP-TSA data and reporting results using HLM, caution must be taken not to abuse or misinterpret the data. To this end, several observations are in order. First, in this analysis, the reliabilities associated with the slope parameters were found to be low. This could be due to low slope parameter variance estimates indicating relative stability of slope

parameters across school. Additionally, low reliabilities could be due to an excessive sampling error variance estimate. This excessive sampling error variance estimate may be due to under specification of the LEVEL-1 model (i.e. inadequate number of explanatory variables in the LEVEL-1 model). If the LEVEL-1 model is under specified, the resulting slope parameter estimates will be biased which may make the LEVEL-2 model parameter estimates, their variance estimates, and t-tests inaccurate.

Second, in the LEVEL-1 and LEVEL-2 models, linear relationships are assumed. In some cases, as seen from the attached graphs, relationships may not be linear. The preferred method of avoiding this problem is to dichotomize all of the predictor variables in the LEVEL-1 and LEVEL-2 models. However, this must not be done arbitrarily since the manner in which a variable is dichotomized may influence the overall results. Further, dichotomizing variables can lead to a loss of important information.

Finally, HLM models assume that the predictor variables are measured without error. While gender and race are less susceptible to measurement error, other variables may be subjected to a large amount of measurement error since they are self reported by eighth grade students. This measurement error not only contributes to the overestimation of the sampling error variance but depending to the predictors can also lead to the violation of homogeneity of variance assumptions made in the LEVEL-1 and LEVEL-2 models (e.g. variability of the average school achievement of low SES schools and high SES schools may be smaller than the variability associated with medium SES schools).

## Data Source

Data that was received from the National Center for Educational Statistics included (a) NAEP Trial State Assessment Almanacs and (b) data files for the state of Mississippi. This data was provided to the researchers under special confidentiality codes.

## Results of HLM Analysis

Within-school models

Table 2 shows the results of the unconditional model for the mathematics achievement of grade 8 students in Mississippi. The within-school models provide the average within-school parameter estimates. The table illustrates that the average achievement score in math for grade 8 students in Mississippi is 249.79. Because of the centering that was performed on the student level predictor variables, the achievement scores represent the average achievement in each school at the average gender, race/ethnicity, SES, and frequency of computer use.

Table 2

Results from unconditional HLM model

WITHIN-SCHOOL PARAMETER	Coefficient	Reliability	t-ratio	p-value
INTERCEPT	249.79	0.78	151.55	0.001
RACE/ETHNICITY	-31.3	0.16	-12.83	0.001
GENDER	-4.85	0.13	-2.648	0.008
SES	5.74	0.06	2.36	0.018
COMPUTER USE	2.01	0.18	1.76	0.078

Table 2 also contains the reliability and parameter variance estimates for each of the within-school parameters. The reliability is the proportion of the total variance that is parameter variance. This parameter variance is what will try to be explained in the between-schools models. The reliability estimates contained in Table 2 range from a maximum of .78 for the intercept parameter to a minimum of .06 for the SES parameter. These results indicate that approximately 78% of the variance around the intercept parameter is parameter variance and has the potential to be explained. Similarly, 16%, 13%, and 6% of the variance surrounding the race/ethnicity, gender, and SES parameters, respectively, are parameter-variance that will try to be explained with the school level variables.

#### Between-school models

Tables 3 through 6 contain the results of the between school models. The first model attempts to explain the parameter variance surrounding the within-school intercept. The results in Table 3 show that the percentage of minority students in a school has a significant association with the average achievement of the school. The negative coefficient indicates that lower average school achievement is associated with higher percentages of minority students. This result is further illustrated in Figure 1. The results show that no other school level predictor was significant at the .10 level; however, the average frequency of computer use for the school had a p-value of .18.

Table 3

Predictors of average school achievement for grade 8

WITHIN SCHOOL PARAMETER			
Between-school predictor	Coefficient	T-ratio	p-value
<b>INTERCEPT (AVERAGE ACHIEVEMENT)</b>			
Intercept	271.07	13.30	0.0001
Proportion of minorities	-32.41	-7.12	0.0001
Proportion of females	6.00	0.52	0.601
Average SES	5.51	0.50	0.618
Computer availability/access	4.26	0.62	0.535
Average frequency of computer use	4.61	1.34	0.179
Reliability		.60	
Parameter variance		72.00**	
Proportion of parameter variance explained		.61	

Note: \*\* $p \leq .01$

Table 3 also shows that the reliability was .60 and the parameter variance, although less than the conditional model, was still significantly different from 0 indicating that there is more parameter variance that can be explained. Finally, the results show that the model was able to explain 61% of the original parameter variance.

The results of the between-schools model for the race/ethnicity parameters are contained in Table 4. The results indicate that the average SES level of the students within a school is significantly associated with the achievement difference between minority and nonminority students. The direction of the coefficient indicates that higher levels of SES are associated with

negative values of the race/ethnicity coefficient which means that the achievement of minority students is less than nonminority students.

Table 4

Predictors of race/ethnicity coefficients for grade 8

WITHIN SCHOOL PARAMETER			
Between-school predictor	Coefficient	T-ratio	p-value
RACE/ETHNICITY			
Intercept	-51.10	-1.06	0.289
Proportion of minorities	-5.05	-0.40	0.689
Proportion of females	-18.95	-0.75	0.451
Average SES	-48.73	-2.01	0.044
Computer availability/access	25.83	1.90	0.057
Average frequency of computer use	12.49	1.60	0.109
Reliability		.12	
Parameter variance		48.66*	
Proportion of parameter variance explained		.31	

Note: \*  $p \leq .05$

Since race/ethnicity is a dichotomized variable, the coefficients associated with this variable can be viewed as gaps between the performance of minorities and nonminorities within schools. Therefore, the results indicate that as the average SES level of the student body increases the coefficient or gap will increase. This is shown in Figure 2. Because the intercept term is negative, a decreasing coefficient is moving away from zero; therefore, the gap is increasing

The results of the between-schools model for the race/ethnicity parameter also indicates that the availability/access of computers has a significant association with the achievement difference between minorities and nonminorities. The positive coefficient associated with this variable indicates that higher levels of availability/access of computers are associated with higher race/ethnicity coefficients. Figure 3 illustrates this result and shows that because the intercept is negative, increasing the value of the coefficient is moving the coefficient closer to zero and therefore reducing the difference between the achievement of minorities and nonminorities.

Of the remaining predictor variables none were statistically significant at the .10 level; however, the average frequency of computer use for the school had a value of  $p = .11$ . Table 4 also contains information concerning the reliability, parameter variance, and proportion of parameter variance explained. The table shows that the reliability was .12 and the parameter variance was still significantly large at 48.66 indicating that there is still some parameter variance that can be explained. The table also shows that the model was able to explain 31% of the original parameter variance.

The results of the between-schools model for the gender parameters are contained in Table 5. The results show that the only predictor that is significantly associated with the gender parameter is the average SES level of the student body. The results for this predictor indicate that higher levels of SES are associated with larger values of the gender parameter. Like the previous interpretation of availability/access of computers and the race/ethnicity parameter, the positive coefficient associated with average SES level of the student body indicates that the



difference between the achievement of females and males is smaller with higher levels of average SES. This interpretation can be seen in Figure 7.

Table 5

Predictors of gender coefficients for grade 8

WITHIN SCHOOL PARAMETER Between-school predictor	Coefficient	T-ratio	p-value
<b>GENDER</b>			
Intercept	-27.42	-0.82	0.409
Proportion of minority	-9.94	-1.39	0.163
Proportion of females	16.70	0.89	0.374
Average SES	31.43	1.75	0.080
Computer availability/access	0.35	0.03	0.976
Average frequency of computer use	3.30	0.64	0.523
Reliability		.14	
Parameter variance		44.59*	
Proportion of parameter variance explained		.00	

Note: \*  $p \leq .01$

The results of Table 5 show that the reliability was .14 and the parameter variance was significantly larger than zero again indicating that some parameter variance can still be explained. Finally, the results in Table 5 show that the between-schools model used to explain the parameter variance surrounding the gender within-school parameter did not explain any of the original parameter variance.

The between-schools model for the within-school SES parameter yielded no significant school level predictors. These results and the corresponding HLM statistics are contained in

Table 6. The results show that the reliability was .10 and there is still parameter variance that can be explained. Also, as a result of the nonsignificant model, none of the original parameter variance was explained.

Table 6

Predictors of socioeconomic status coefficients for grade 8

WITHIN SCHOOL PARAMETER Between-school predictor	Coefficient	T-ratio	p-value
<b>SOCIOECONOMIC STATUS</b>			
Intercept	82.80	1.87	0.061
Proportion of minority	-0.58	-0.06	0.952
Proportion of females	-29.01	-1.10	0.272
Average SES	-12.85	-0.54	0.588
Computer availability/access	-3.52	-0.26	0.796
Average frequency of computer use	-8.67	-1.19	0.236
Reliability		.10	
Parameter variance		52.80*	
Proportion of parameter variance explained		.00	

Note: \*  $p \leq .01$

### Interpretations and Implications

The results of this analysis have far-reaching policy implications for schools in the state of Mississippi. In this section, each of the eight questions addressed in this study will be answered followed by a discussion of the policy implications for schools. Finally, the conclusions from these findings are presented along with suggestions for further research.

The first two questions relate to the relationships between availability/access and use of computers and the average school achievement. Question 1 asks if having more computers or greater access to computers increases school achievement. The answer, from our analysis, is that availability/access to computers is not statistically significantly associated with a change in student achievement. However, the impact on student achievement as a result of the frequency of computer use can be detected. While statistically speaking the results do not indicate significance ( $p = .18$ ), the evidence leads one to conclude that there is a level of association between the frequency of computer use and achievement. While statistically this association is weak, the educational implications are important. The conditional model shows that the more frequently the computer is used the lower the average math achievement is for a school. This trend is shown in Figure 5.

The analysis of the first two questions also included an examination of the relationships between school achievement and student body characteristics, such as the percentage of females, minorities, and the average socioeconomic status of the student body. In general, the differences in school achievement cannot be explained by the percentage of females or socioeconomic status of the student body. However, the proportion of minorities in a school is associated with school achievement. As Figure 1 shows, as the proportion of minorities in a school increases the average school achievement decreases.

Questions 3 and 4 focus on the difference between the mathematics achievement of minorities and nonminorities. Figure 3 illustrates the association between computer availability/access and the minority-nonminority achievement difference. The figure shows that as computers were made more available and as teachers had greater access to computers the

difference between the performance of minorities and nonminorities was narrowed. When one looks at the frequency of computer use, it is revealed that in schools where computers were more frequently used, there was a wider gap between the average performance of minorities and nonminorities. While this gap is not statistically significant ( $p = .11$ ), it does show a marked trend which is shown in Figure 6.

The association between the student body characteristics and the difference in minority and nonminority achievement were included in the analysis of questions 3 and 4. A significant association was found for the average student body SES. Figure 2 indicates that as the SES of a student body increases the difference between the achievement levels of minority and nonminority students widens. As shown in Figure 2, the difference in the gap approaches zero for schools with the lowest average SES. Thus, in Mississippi schools with low SES student bodies there is a smaller difference in the performance of minority and nonminority students. The race gap analysis also indicated that there was no relationship between the percentage of minorities or females in a student body and the difference in the achievement of minorities and nonminorities in a school.

The analysis for questions 5 and 6 revealed no association between the achievement difference of female and male students and computer availability/access or frequency of computer use. Further, the analysis indicated no relationship between the percentage of females and minorities within a school and the gender gap. However, it did indicate an association between the average SES level of the student body and the difference between the achievement of female and male students. As Figure 4 illustrates, the difference between the achievement of female and male students was narrower in schools with higher average socioeconomic status.

The final two policy-relevant questions addressed the associations between computer availability/access and frequency of computer use and the performance of low and high SES students. The analysis revealed no significant associations between the within-school SES coefficient and the two policy-relevant computer variables. Additional analyses also indicated that the student body characteristics were not significantly associated with the within-school SES coefficient.

In short, these analyses lead to several interesting conclusions and policy implications. This research attempted to explain variation in average mathematics achievement for eighth grade public school students in Mississippi for the year 1992. While neither availability/access nor frequency of computer use was found to be statistically significantly associated with average school achievement, both variables showed associations with the gap between minority and nonminority students. In fact, in schools where computers were the most available and accessible the gap between minority and nonminority students was significantly reduced.

The implications of this research for state policy makers are provocative. While spending more resources to provide more computers for schools may not lead to improved math achievement, training teachers on more appropriate uses of existing computers may bring about greater improvement in math achievement. For local school policy makers, the implications of this research indicate that computer availability/access seems to be related to reducing the gap between minority and nonminority students. However, this research does not address the many other factors that come into play to improve math achievement. Contrary to some conventional wisdom that computers in the schools will improve math achievement, a conclusion of this

research is that there is not a strong association between computer availability/access or frequency of use and math achievement.

#### Recommendation for Further Research

One of the basic assumptions of Hierarchical Linear Modeling is that relationships are linear. As the researchers were studying this model and the characteristics of several variables, it was observed that often the assumption of linearity may be violated, and at times, quite severely. As shown in figures 7, 8, and 9, other nonlinear lines may better fit the data. Specifically in Figure 8, the line may decrease between 0 and 0.4, stabilize between 0.4 and 1.0, then decrease quite drastically between 1.0 and 1.6. The implications of this violation deserve further investigation.

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# Average School Achievement by Percentage of Minorities in Student Body

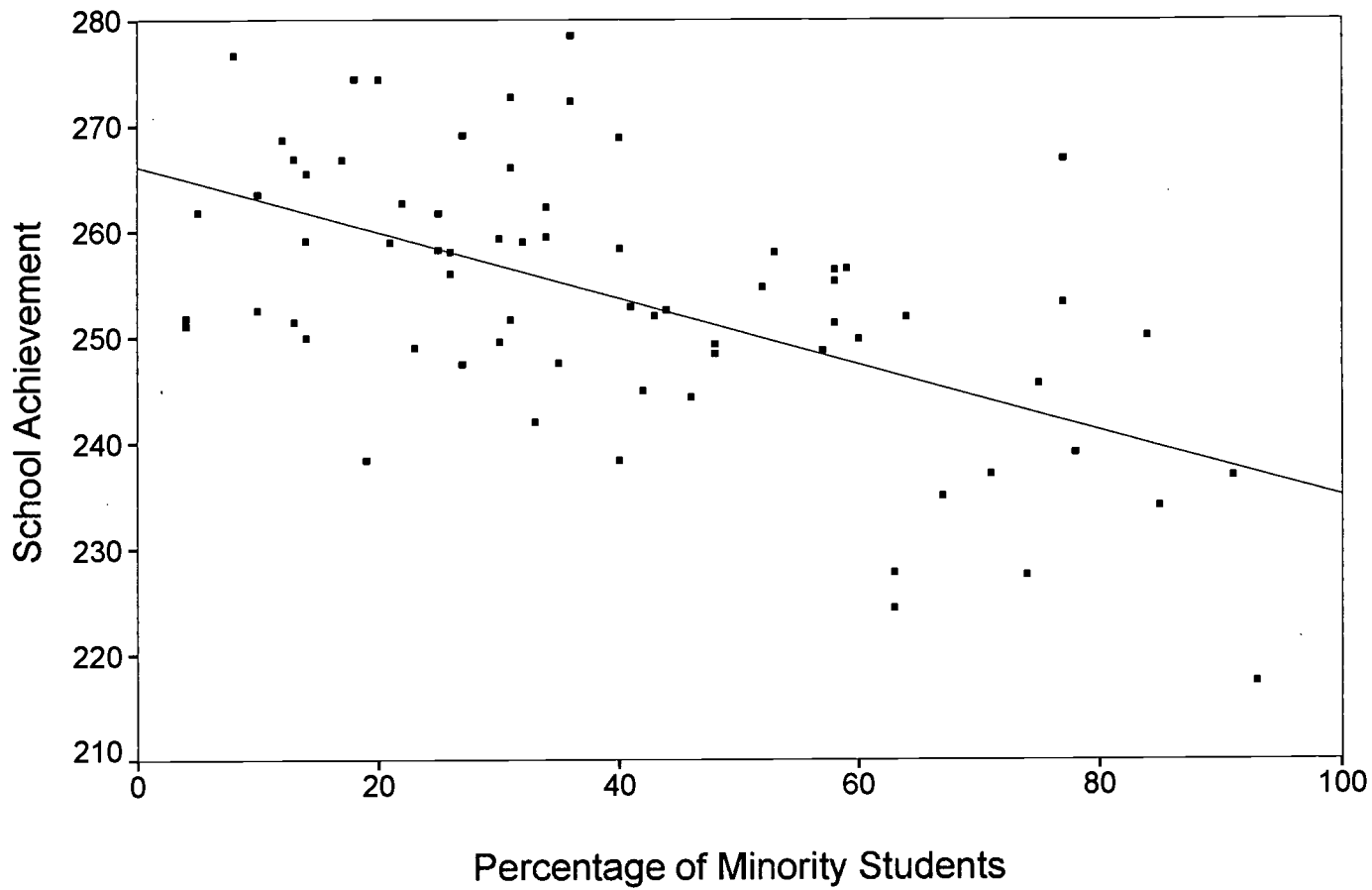


Figure 1

# Difference in Minority/Nonminority Achievement by Student Body SES

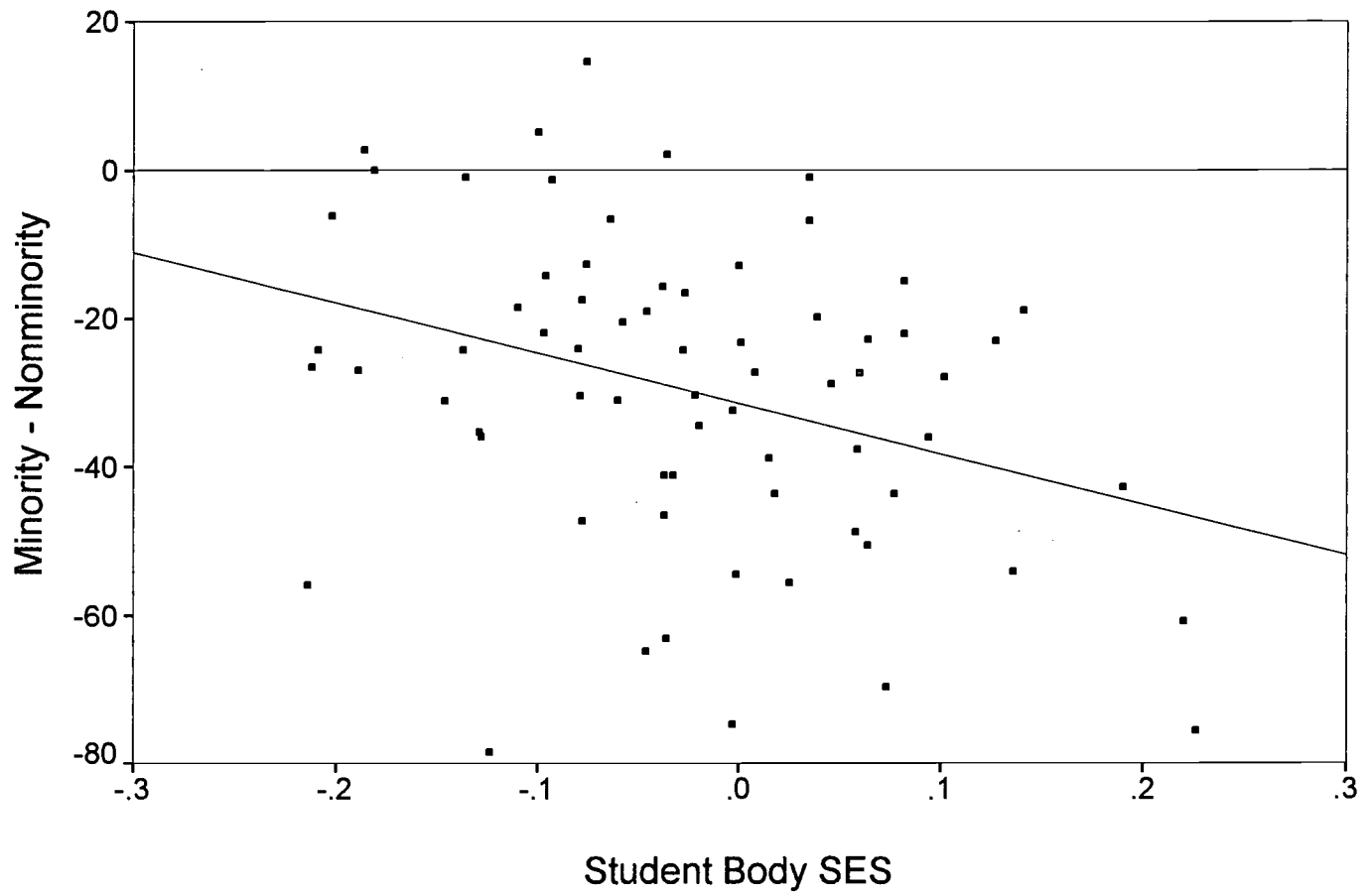


Figure 2

# Difference in Minority/Nonminority Achievement by Computer Availability/Access

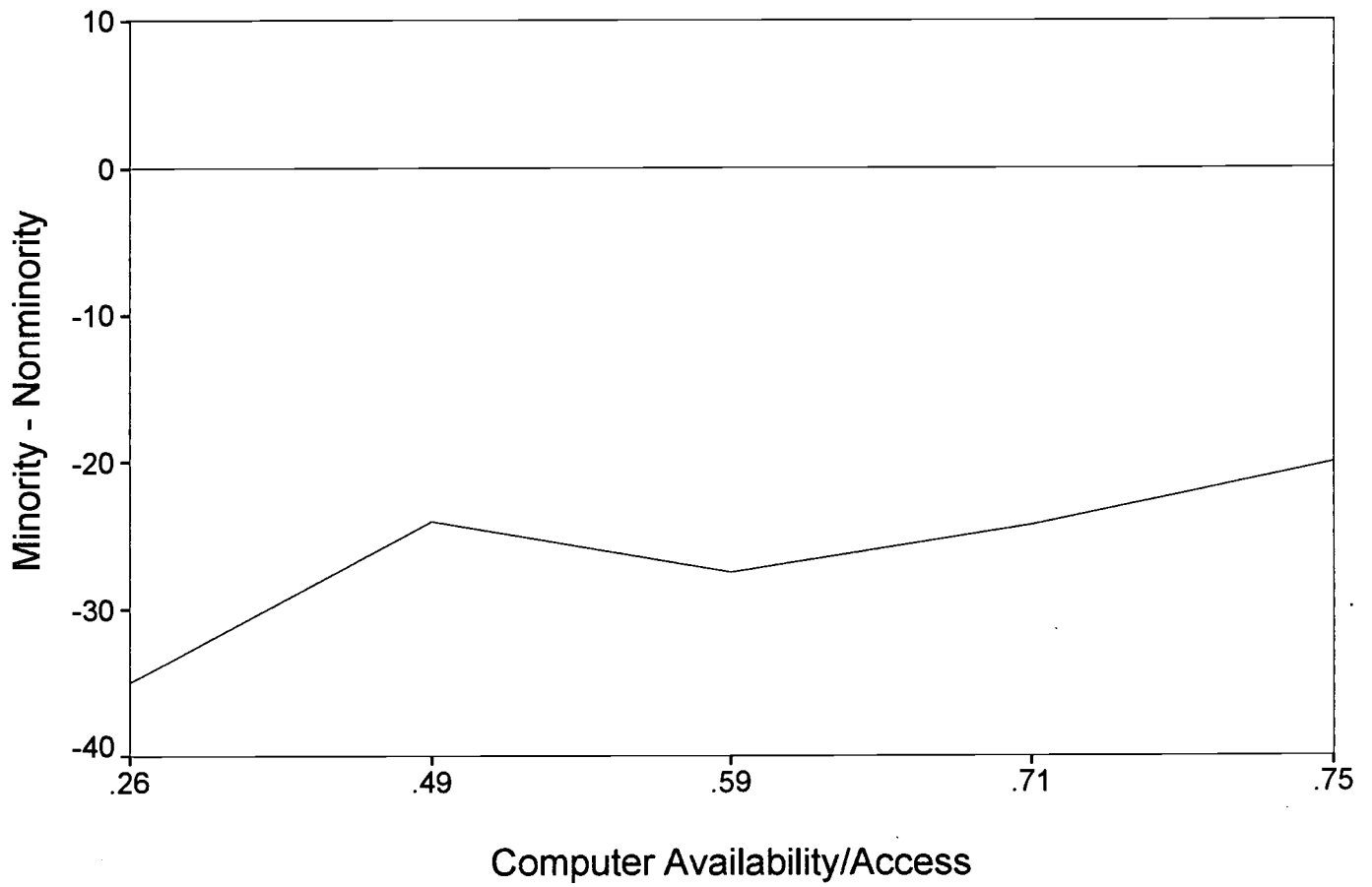


Figure 3

# Difference in Female/Male Achievement by Student Body SES

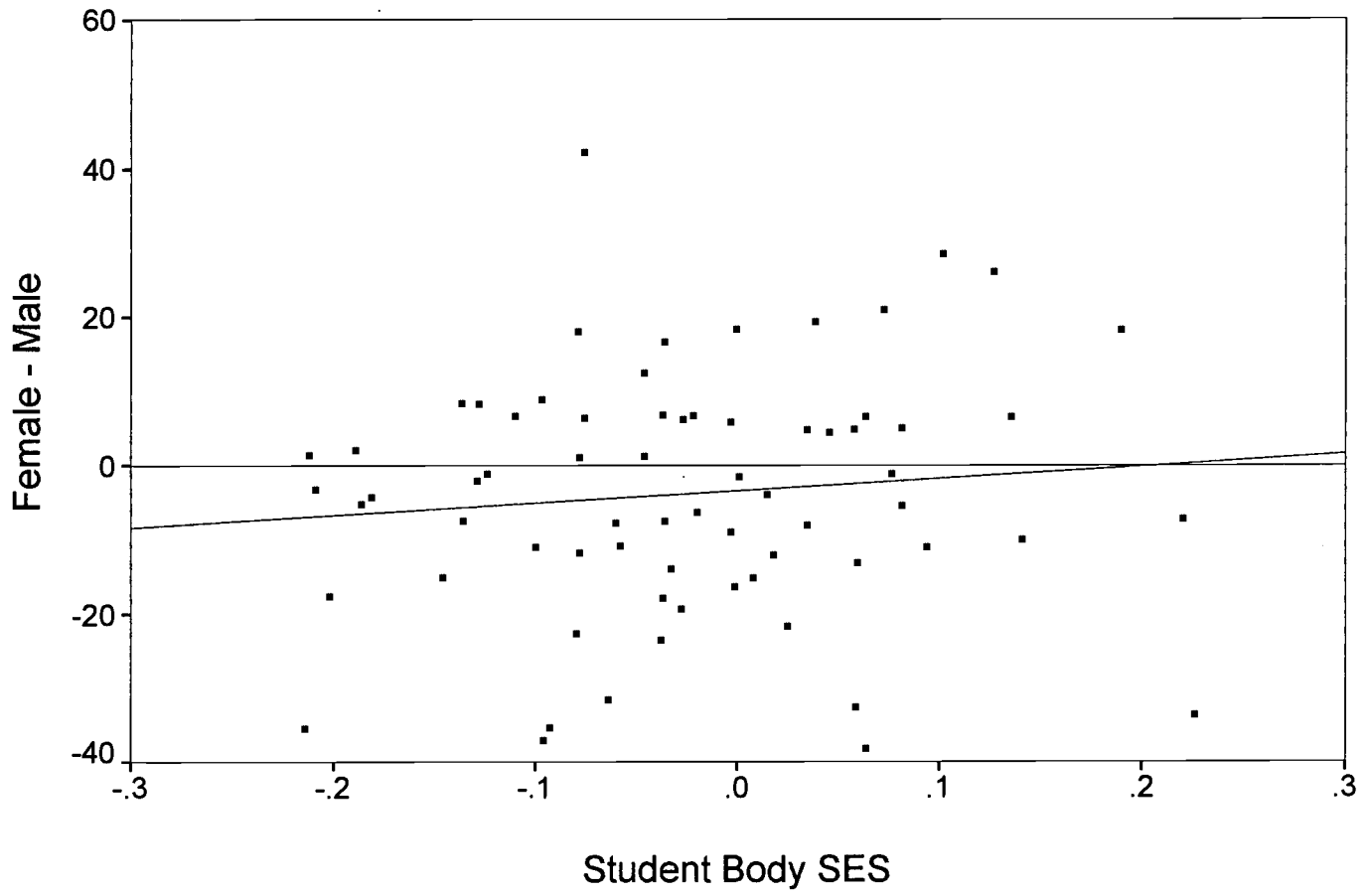


Figure 4

# Average School Achievement by Frequency of Computer Use

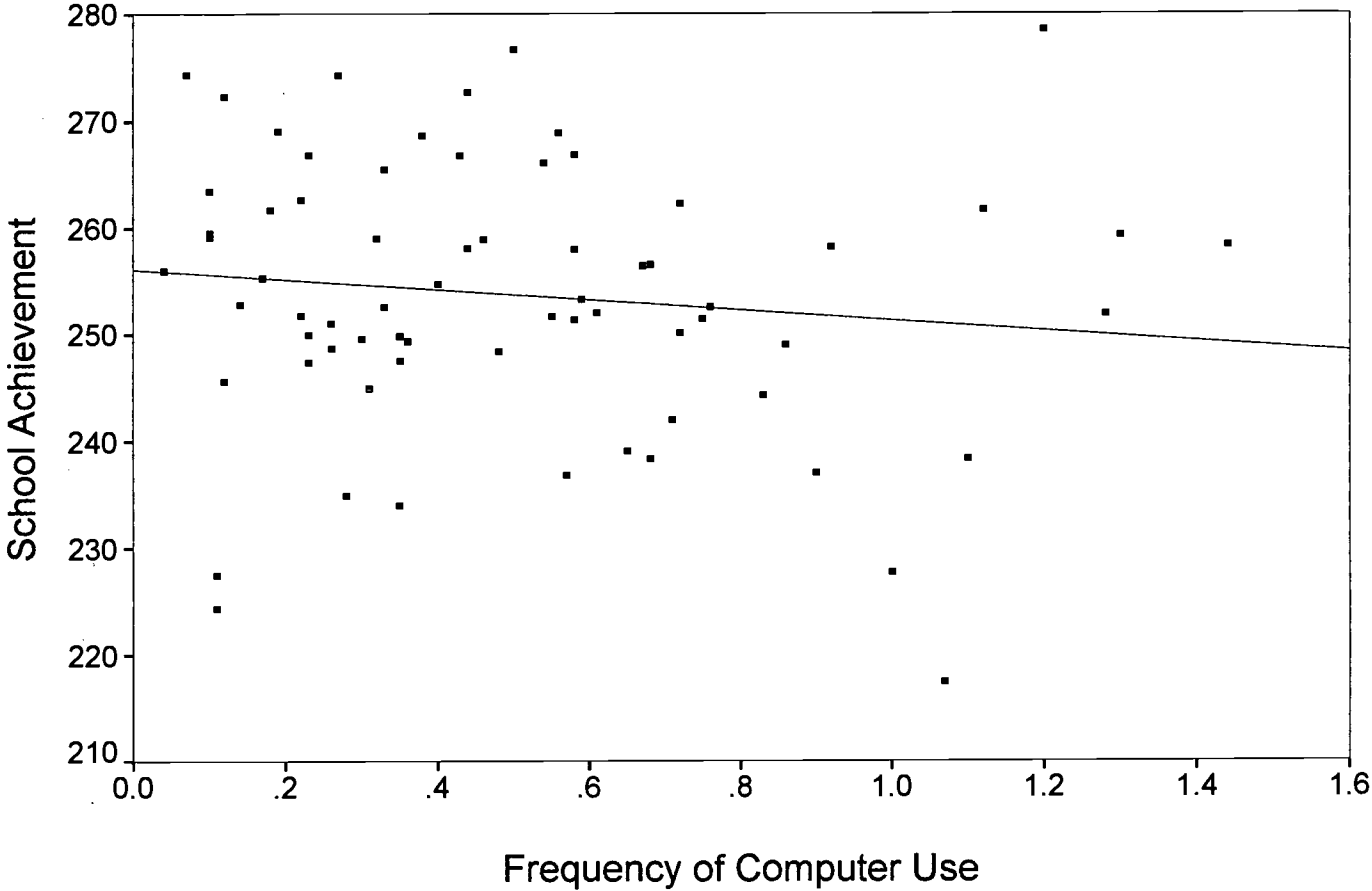


Figure 5

# Difference in Minority/Nonminority Achievement by Frequency of Computer Use

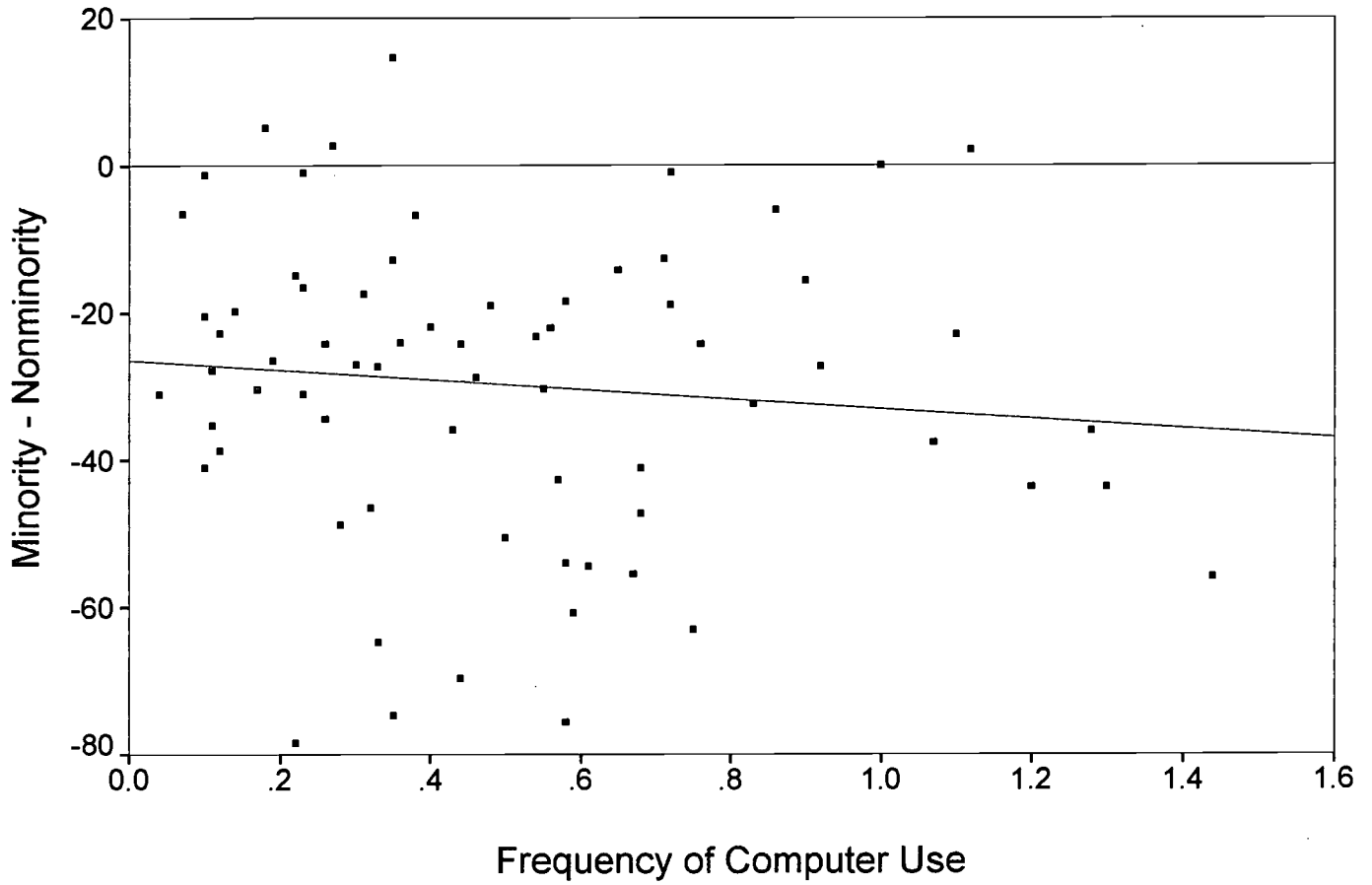


Figure 6

# Average School Mathematics Achievement by Percentage of Minorities in Student Body

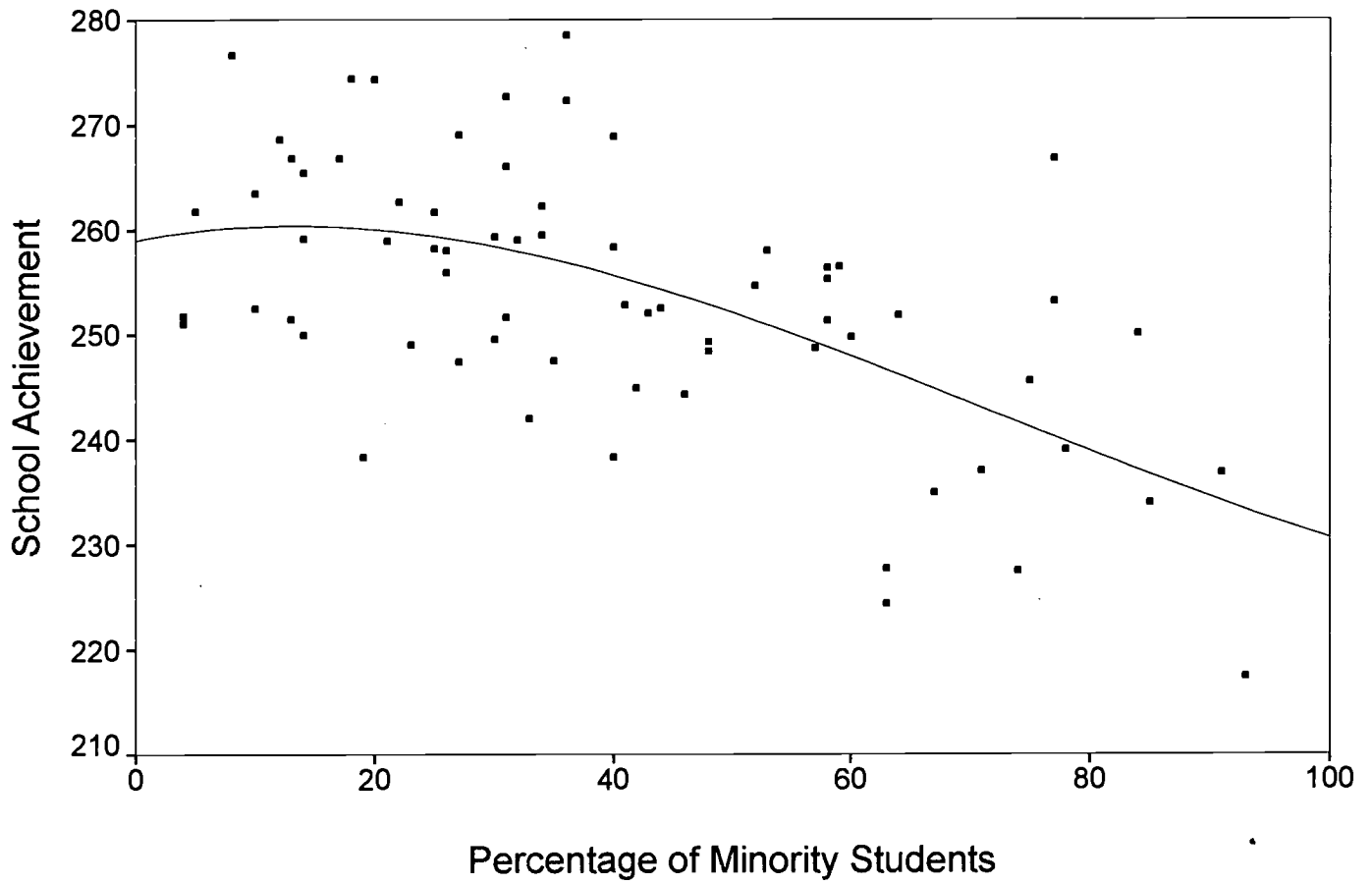


Figure 7



# Difference in Minority/Nonminority Achievement by Frequency of Computer Use

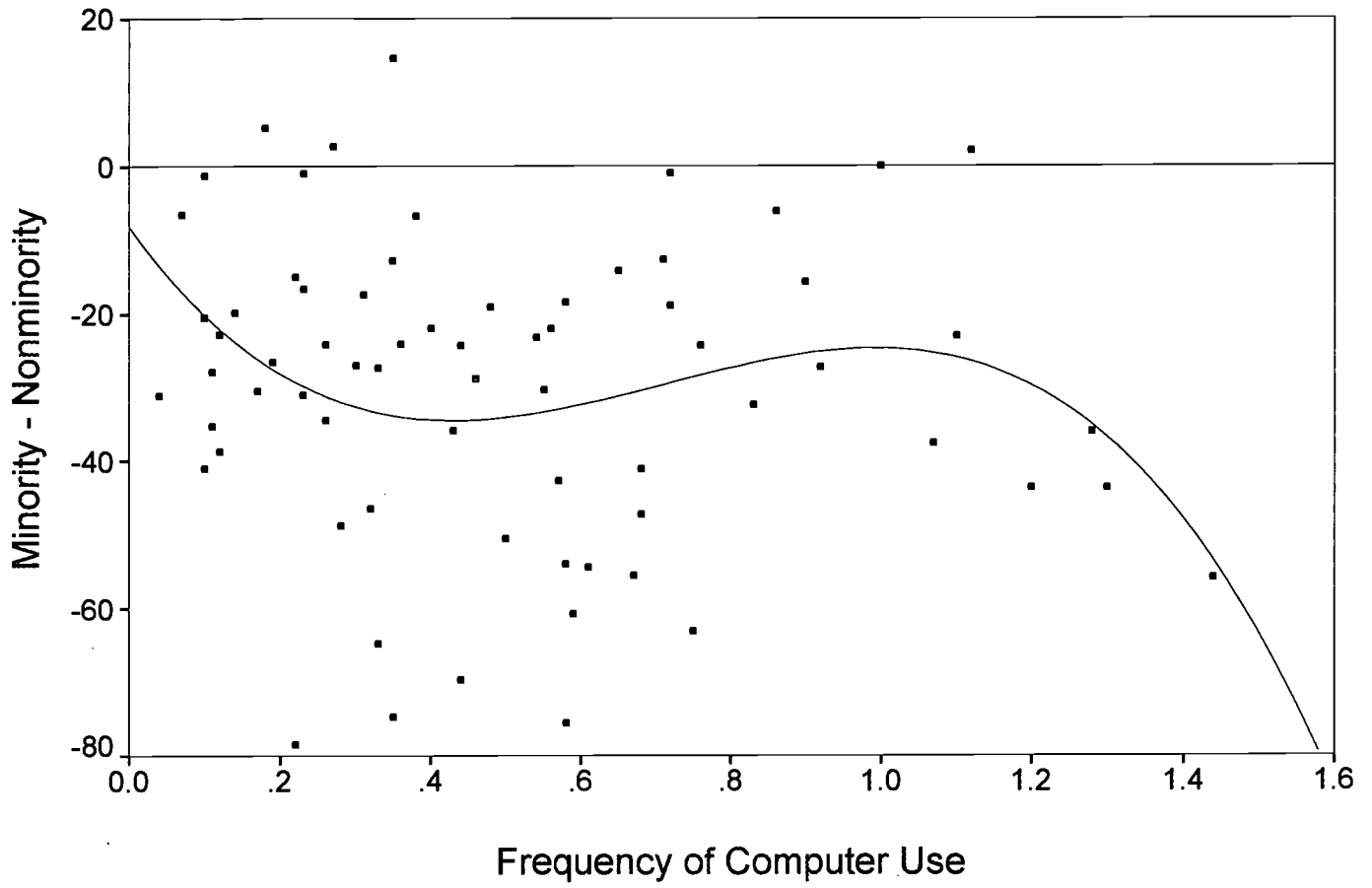


Figure 8

# Difference in Minority/Nonminority Achievement by Computer Availability/Access

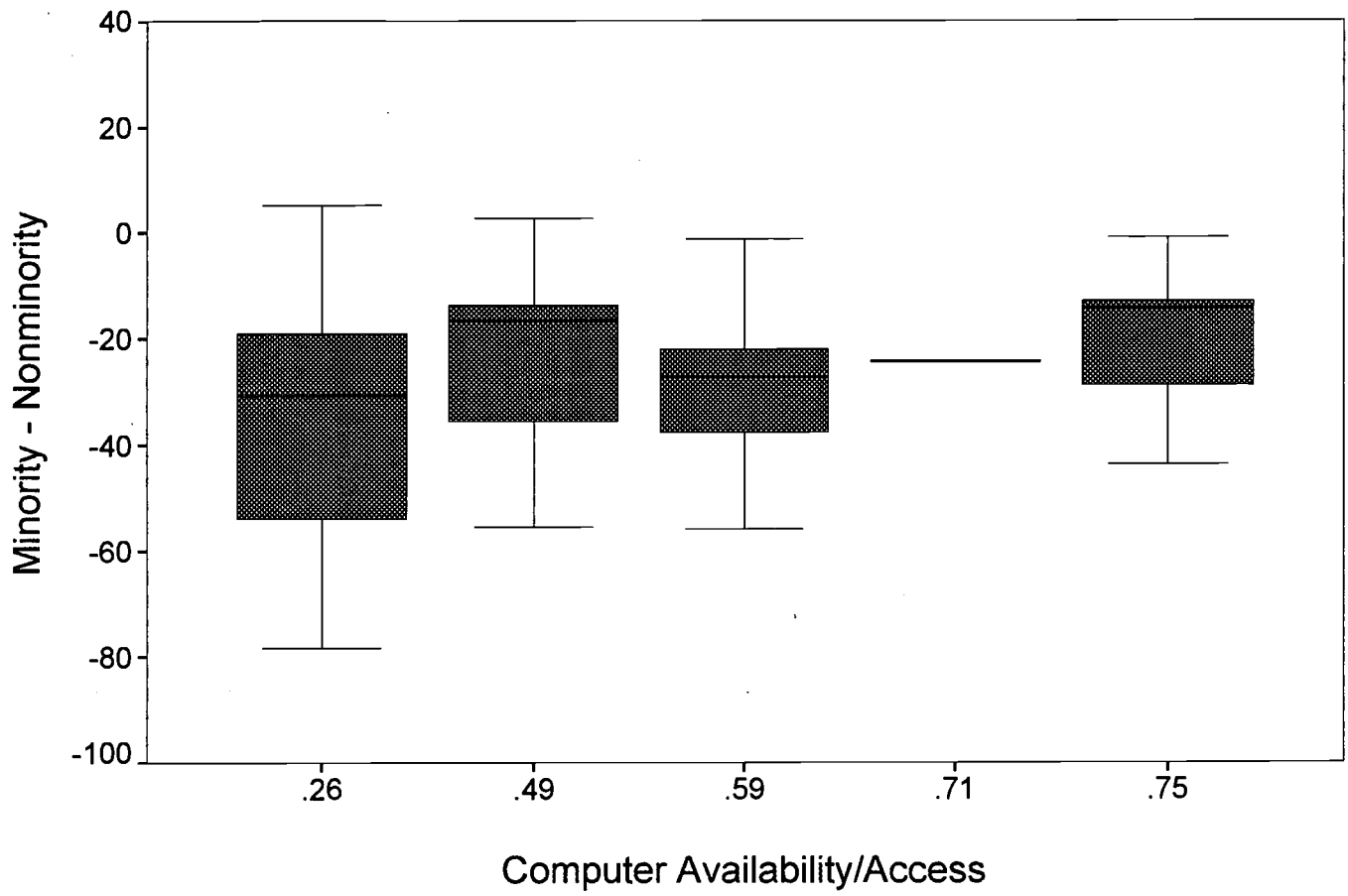


Figure 9

TM 025681

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