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ABSTRACT

This report examines the most recent middle school data from the National Assessment of Educational Progress (NAEP) to investigate how selected dimensions of instructional practice are related to higher-order learning of middle-grade students. In particular, the paper: (1) outlines the theoretical basis for prescribing middle level instructional practice; (2) conducts multiple regression analyses to investigate how different instructional practices affect student learning; and (3) finds small effects on student higher-order learning for experiments in science, but no effects for hand-held calculator use in mathematics. Concluding discussion focuses on two issues: whether greater higher-order learning can be achieved without sacrificing some of the other content now covered in the middle grade curriculum; and whether a mass education system such as the nation's middle grade schools can actually develop the staff expertise and implement the activities needed to greatly upgrade the learning environment for higher-order skills. Appended are descriptions of skills covered by NAEP document exercises in mathematics and science subtests. Approximately 70 references and readings are listed. (RH)

Center for Research On Elementary & Middle Schools

Report No. 25

July, 1988

INSTRUCTIONAL PRACTICES IN THE MIDDLE GRADES: NATIONAL VARIATIONS AND EFFECTS

James M. McPartland and Shi-Chang Wu

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The Center

The mission of the Center for Research on Elementary and Middle Schools is to produce useful knowledge about how elementary and middle schools can foster growth in students' learning and development, to develop and evaluate practical methods for improving the effectiveness of elementary and middle schools based on existing and new research findings, and to develop and evaluate specific strategies to help schools implement effective research-based school and classroom practices.

The Center conducts its research in three program areas: (1) Elementary Schools; (2) Middle Schools, and (3) School Improvement.

The Elementary School Program

This program works from a strong existing research base to develop, evaluate, and disseminate effective elementary school and classroom practices; synthesizes current knowledge; and analyzes survey and descriptive data to expand the knowledge base in effective elementary education.

The Middle School Program

This program's research links current knowledge about early adolescence as a stage of human development to school organization and classroom policies and practices for effective middle schools. The major task is to establish a research base to identify specific problem areas and promising practices in middle schools that will contribute to effective policy decisions and the development of effective school and classroom practices.

School Improvement Program

This program focuses on improving the organizational performance of schools in adopting and adapting innovations and developing school capacity for change.

This report, prepared by the Middle School Program, examines the most recent middle school data from the National Assessment of Educational Progress to investigate how selected dimensions of instructional practice are related to higher-order learning of middle grade students.

Abstract

Instruction at the middle grades should encourage active learning by students and stimulate their development of higher-order skills. This two-dimensional prescription for middle level instructional practice -- active learning for higher-order skills -- is derived from current theories about the unique aspects of student development and curriculum content at the middle grades. This paper (1) outlines the theoretical basis for prescribing middle level instructional practice, (2) conducts multiple regression analyses to investigate how different instructional practices affect student learning, (3) finds small effects on student higher-order learning for experiments in science, but no effects for hand-held calculator use in math.

Introduction

Both specialists in early adolescent development and specialists in curriculum design come to the same conclusions about instructional practice in the middle grades.

Specialists in early adolescent development note several unique features of this stage of human life that call for school learning experiences in which students play active roles and which involve higher-order cognitive tasks (Hill, 1984; Elder, 1968; Canter, 1984). Both personal development and cognitive development considerations are involved. Early adolescents are undergoing key transitions in how their behavior is regulated. They are moving from externally regulated behavior to more co-regulation of behavior with significant adults to self-regulated behavior. Early adolescent students are becoming interested in more autonomy, independence from elders, and greater self-reliance.

To respond to these students' interests and to assist in the age-appropriate transitions, middle schools should design classroom activities in which students can play a more active role than is possible in the traditional teacher lecture and student recite mode. According to this view, more hands-on activities and more opportunities for initiative -- with close teacher supervision rather than total teacher direction -- are appropriate for early adolescents. In the cognitive area, there is less agreement about the unique aspects of the early adolescent stage, but the dominant theory is that this age group needs opportunities to develop higher-order competencies, such as understanding and comprehension skills in reading, problem solving and reasoning skills in mathematics and science, and analytic and critical thinking skills in other subjects.

Curriculum specialists in major subjects are also calling for learning activities and classroom environments that go beyond teaching facts to be memorized in science or history, teaching mechanical rules and skills of computation in mathematics, or teaching decoding in reading. Commission reports of curriculum experts have recommended instructional reforms that incorporate activities for higher-order learning. In mathematics, this involves more emphasis on problem solving, estimation and approximation to judge reasonableness of results, and other mathematical thinking. reasoning, and application skills. In reading and social studies, it involves more focus on comprehension, understanding and critical thinking competencies. In science, it involves greater attention to appreciation of methodologies and scientific inquiry, and the development of skills to design approaches to gather information and to reason with evidence.

Nevertheless, improvements in instructional activities and learning environments to meet these prescriptions have not been widespread or lasting in the middle grades (Weiss, 1978, Report of the 1977 National Survey of Science, Mathematics and Social Studies Education; National Science Board, 1983; Rutherford and Ahlgren, 1988; Campbell and Fey, 1988; Brandt, 1988). Although the reasons for the small amount of actual change in classroom practice are not well understood, some impediments can be surmised.

First, the level of teacher expertise is not sufficient in many localities for effective activity-based student-centered instruction. Teachers not only need thorough training in the particular subject to give them expertise and confidence in designing instructional activities, they need skills in high cognitive level questioning and techniques to guide student discovery and thinking processes.

Second, the activities found in curriculum guides and textbook supplements in each subject are not always clearly defined or well designed to both motivate students and stimulate their higher-order growth. For example, science laboratory experiments -- which seem to be widely accepted as a good way to meet the prescriptions -- can become a tedius sequence of predetermined steps to verify a pre-specified textbook conclusion. Proper implementation may require appropriate teacher questions and the establishment of an inquiry process during the activity to be effective for higher-order learning.

Method

We will use data from the 1985-86 National Assessment of Educational Progress (NAEP) to investigate how selected dimensions of instructional practice may influence higher-order learning of middle grade students. NAEP is the semi-annual federal testing project that covers selected subjects in alternate assessment years. In 1985-86 NAEP covered science, mathematics and reading in grade 7 for the middle grades. We were unable to obtain the reading test data, which are being withheld from public use until some unexpected irregularities can be rectified by Educational Testing Service (ETS), the contractor for the 1985-86 assessment.

The greatest strength of the NAEP test data is the comprehensiveness of coverage of the dimensions of each subject being assessed. Items are included to cover dimensions of both low and high cognitive complexity, although very little research with NAEP data has taken advantage of these distinctions.

We obtained information from ETS about which test items in mathematics and in science were designed to measure each level of cognitive complexity, and we developed corresponding subtest scores in each subject. Because NAEP uses a complex sampling design in which different sets of test items are given to random blocks of students, we developed a formula to calculate a subtest score for each individual that takes into account the number and difficulty of the particular items assigned to each student. The formula is:

$$\text{Subtest score} = \frac{\sum w}{n}$$

where w = the weight applied to each correct answer (the difficulty factor of the item) which is equal to 1 minus the national percentage correct on that item;

n = number of subtest items administered to the particular student

The following three subtest scores were measured in science (see Appendix for details):

1. Science Knows Test (Low Complexity)
2. Science Understands Test (Medium Complexity)
3. Science Integrates Test (High Complexity)

The following five subtest scores were measured in mathematics (see Appendix for details):

1. Mathematics Skills Test (Lower Complexity)
2. Mathematics Knowledge Test (Lower Complexity)
3. Mathematics Routine Applications Test (Lower Complexity)
4. Mathematics Understanding/Comprehension Test (Higher Complexity)
5. Mathematics Problem Solving/Reasoning Test (Higher Complexity)

Our research goal is to identify factors in the middle grade classroom learning environment that especially encourage student growth on the subtests of higher order skills, allowing for the possibility that the same factors may also facilitate learning on the other subtests. Associated with every student in the 1985-86 sample is information from the teacher who provided instruction to the student in the tested subject. The information obtained from NAEP science teachers includes whether each teacher has expert training in the subject and how often the teacher uses science experiments in the science courses for seventh graders. The information obtained from NAEP math teachers includes data on expert training in math and on the use of hand-held calculators in math instruction.

We can use NAEP data to study whether teachers with expert training in their subject have especially strong effects on student higher-order learning in science or mathematics. In science, we can use NAEP data to study the impact of science experiments, which should provide the kinds of active learning activities and involvement in extended complex tasks that might be expected to foster student learning of higher-order skills. In mathematics, the NAEP measures concerning use of calculators also provide an opportunity to test ideas about higher-order learning. It is possible that using calculators in math could free up time usually spent on drill and practice in the mechanics of math for use on learning activities for problem-solving and reasoning skills. We will use NAEP data to examine this possibility.

Subtest Validity

Before conducting our analyses, we need to verify that the subtest scores that we created truly reflect different levels of cognitive complexity. Tables 1 and 2 present tabulations to study the validity of the hierarchy of the math and science subtests.

Table 1 presents the average probability that an item will be answered correctly in each subtest, by student sex. Comparing this average probability on different subtests provides a good idea about what kinds of skills are most difficult for seventh grade students, because those subtests with the lowest probability of correct answers will contain the collection of test items that students find most difficult. Table 1 shows a regular trend from more complex subtests to less complex subtests in the average probability of correct answers in both science and mathematics, which means that American seventh graders have more difficulty with high complexity subtests covering higher-order skills . For example, the Total column of Table 1 shows an average item probability correct of .356 for the high complexity science test, .409 for the medium complexity science test, and .442 for the low complexity science test. The trend in Table 1 across math tests is similar: in the Total column the probability rises from .264 for the math test of highest complexity to .410 for the math test of lowest complexity.

Previous research has shown sex contrasts in test performance across different subjects, with females doing less well on the average than males in science and math as students get older (Wilkinson and Marrett, 1985; Maccoby and Jacklin, 1974). These differences have usually been attributed to the powerful sex-role socialization and sex-role stereotyping that continue in schools, which influence females away from interest and achievement in science and math (which are often viewed as "male" subjects). Because higher-order skills are more likely to be introduced in later school grades and are more likely to be mastered by students with greatest interest in the subject, sex differences favoring males should be largest (or differences favoring females should be smallest) on higher-order subtests of math and science. This prediction is examined in Tables 1 and 2.

Table 1 shows sex differences in performance on various subtests, with patterns in the direction and size of the sex differences that further confirm the hierarchy of subtests by level of complexity. Table 2 uses regression coefficients to show these same patterns and adds statistical controls for differences in the age distribution of students. Table 2 shows that sex differences favoring males are largest for the subtests requiring more higher-order skills in both science and math. In mathematics, the results favor females for the subtests of lower complexity; while in science, the male advantages are smallest for the subtests of lower complexity. Because these sex differences conform to the predictions made earlier based on assumptions about sex-role socialization, these results further support the hierarchy of NAEP subtests according to complexity and higher-order skills.

Given these assurances that the NAEP subtests form a hierarchy, we turn now to our investigations of middle school learning environments.

Results

Science Test Performance

We conducted analyses to study how each of three factors related to student performance on science subtests. The three factors are (1) the use of science experiments in classroom instruction; (2) specialized science teacher for instruction, and (3) student background and school demography. Each of these factors is measured in NAEP by multiple variables. Use of science experiments is measured by 7 variables, including how often students do science experiments in class, how often teachers demonstrate science experiments in class, and the quality of lab facilities and equipment. Specialized science teacher is measured by 8 variables, including whether the teacher majored in science at college, has college degrees in science, and is certified as a science teacher. Student background and school demography is measured by 11 variables, including student sex, race, age, family socio-economic status, school location, and race distribution of student body.

Table 3 summarizes how each of these factors is associated with student performance on the three science subtests. We present the multiple correlation coefficient (Total R^2) when a subtest is regressed on the entire set of variables of each factor. And, to examine the relationship of each factor on a subtest when the effects of the other two factors have been removed, we present the unique percent of variance accounted for by each factor.<*>

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<*> Unique percent variance accounted for by Factor A = $R^2_{ABC} - R^2_{BC}$

Unique percent variance accounted for by Factor B = $R^2_{ABC} - R^2_{AC}$

Unique percent variance accounted for by Factor C = $R^2_{ABC} - R^2_{AB}$

The direction of effects is found from the regression coefficients not shown in Table 3. See F.N. Kerlinger and E.J. Pedhagur, *Multiple Regression in Behavioral Research*, pp. 297-305.

Although the relationships are quite small, we find that the use of *science experiments* in classroom instruction is *most useful* for fostering student growth in *higher-order skills* as measured by the subtest of high complexity. Science experiments also contribute to better student performance on other science subtests, but have less impact on the medium complexity subtest and least impact on the lowest complexity subtest. Table 3 shows multiple correlations for this factor of .010, .007, and .006 and unique effects for this factor of .010, .007, .004, and these values are largest for the high complexity subtest and smallest for the low complexity subtest. Our earlier predictions about classroom learning environments for higher-order learning are confirmed by this pattern of increasingly strong relationships of science experiments on science test performance as the content of the test increases in higher-order complexity. But because all of the relationships are quite small, it seems clear that no major advance in higher-order learning will come about simply by introducing more science experiments as they are *typically implemented* in American seventh grade classrooms.

The other factors we analyzed for Table 3 have more powerful overall effects on science learning, but do not have differential impact on the subtests of different complexity. Specialized science teachers contribute to higher student performance on science tests with about equal impact on each subtest. Again, the relationships are quite small, however. Not surprisingly, student background and school demography are by far the most powerful of the three factors in accounting for student test performance, with no trend of differential impact for test complexity.

Thus Table 3 provides evidence that different factors in the classroom environment contribute to different types of student learning in science. Specialized teachers boost student science achievement in all aspects, with about equal impact on learning of low, medium and high complexity competencies. Classroom practices involving science experiments, which usually encourage active student learning on extended complex tasks, are more effective in fostering higher-order skills in science. However, the small size of the relationships implies that there will be no simple methods to upgrade classroom practice for higher-order learning.

Mathematics Tests Performance

We conducted parallel analyses of how different factors are related to student performance on mathematics subtests. The factor for student background and school demography uses exactly the same 11 variables we used in the previous analyses of science performance. The factor for specialized teachers uses the same kinds of items used for the previous analyses, but the items refer to mathematics as the subject matter of specialization in teacher training and current teaching assignment. A final factor uses 4 variables to measure use of hand-held calculators in mathematics instruction.

Table 4 summarizes the results of our analyses of sources of variation in math subtests. In contrast to our previous analyses of science performance, we do not get findings for mathematics that help us understand what factors matter most for higher order learning in this subject. The math subtest of highest complexity (problem solving/reasoning) shows the weakest relationship to every factor, including student background. This means that properties of the subtest itself may underlie any school factor trends in relationships rather than differential impacts of learning environments.

The use of calculators factor does not matter at all in accounting for variance in these math subtest scores. Not only are the correlations in Table 4 below conventional levels of statistical significance for most subtests, the direction of the relationship is not consistently positive for the separate variables of this factor (the mixed signs of regression coefficients are not shown here). Thus, while there may be other unmeasured classroom practices that are necessary for higher-order learning in math, these data do not suggest that the use of calculators in math instruction serves this function.

Table 4 shows that specialized math teachers do enhance the learning environment to encourage better student math test performance on all subtests, but we cannot conclude that specialized math teachers are especially effective for higher-order skills. Actually, the relationships are slightly smaller for the higher complexity math subtests, but we are reluctant (because of the properties of the subtest) to interpret this to mean that specialized teachers are least important for higher-order learning.

Discussion

Instructional practice for active learning of higher-order skills will continue to be a major issue for middle grade education. The issue involves several general questions for which our NAEP analyses give a few clues but no clear answers.

One question is whether greater higher-order learning can be achieved without sacrificing some of the other content now covered in the middle grade curriculum. This is the question of a potential tradeoff between breadth of content coverage and depth of any one topic. The potential tradeoff may occur because the extra time needed for the discussion and projects that foster higher-order thinking skills will come at the expense of "covering" a smaller proportion of the textbook units in the subject. We did not see any evidence in the NAEP data of such a tradeoff in mathematics or science -- the correlations between subtests of different levels of complexity were positive, though not as large as subtest intercorrelations in the conventional test batteries used by most school systems.

A second question is whether a mass education system such as the nation s middle grade schools can actually develop and implement the activities and staff expertise to greatly upgrade the learning environment for higher-order skills. Or, at best, can we realistically expect only a small fraction of exceptional teachers or exceptional schools to build such environments? Our analyses of NAEP are consistent with earlier suggestions that there are no easy methods, such as providing hand calculators in mathematic classes or mandating more laboratory experiments in science classes, to bring about large effects. A teacher knowledgeable in the subject who can ask the right questions and motivate the proper spirit of inquiry may be a necessary ingredient along with activities or lessons that will accommodate such expertise and style. Because such a combination of staff and curriculum for higher order learning is not now typical of middle grade education, major new national investments appear necessary to attract or train highly skilled and resourceful teachers and for developing the classroom activities that foster thinking skills.

Although the 1985-86 NAEP data, like most large surveys, can not provide much detailed information on actual classroom practice, we will pursue some additional topics of middle grade education with these sources. First, we will go further into the best feature of NAEP by further subdividing the test exercises into subtests that distinguish content as well as complexity in the subject. For example, by studying only the biology items for seventh graders who studied only biology in their science classes, we may get a clearer picture of the classroom activities that foster different kinds and levels of learning. Second, we will obtain the NAEP reading tests to contrast relationships with seventh grade student characteristics across math, science and reading domains at different levels of complexity. These investigations may clarify issues of sex-role socialization to specific subjects across the grades and how schools may progress toward equalization of the learning opportunities for males and females. Third, we will study additional factors of classroom practice and learning environment, including the specific textbook or workbooks used for instruction in each class (and whether hands-on activities are included) and other aspects of teachers' background and training, to search for additional clues about how higher-order learning is encouraged in the middle grades.

Appendix

The following are descriptions provided in NAEP documents on the skills covered by the exercises in each *mathematics* subtest:

Problem Solving Reasoning

This category of exercises is intended to assess higher-order thinking skills. Therefore, the exercises require processes that are intellectually more complex than the application of skills or the understanding of a single concept.

In the area of problem solving, the exercises require such processes as identifying and using a problem-solving strategy, screening relevant from irrelevant information, formulating a problem or selecting a model of a problem situation, determining what information would be needed to solve a problem, or organizing given information to represent the problem. The category also includes such processes as formulating generalizations or testing their validity, recognizing patterns and describing or symbolizing the relationships, or informally making references. In contrast to exercises in the categories of routine problem solving and understanding, an exercise in this category might ask the student to identify *all* needed information to solve a non-routine problem.

Routine Application

Routine mathematical application refers to the use of mathematical knowledge, skill, and understanding in solving problems that are routine in the sense of familiarity -- similar problems would have been studied either in the course of instruction or in a textbook assignment. The student is thus presumed to have had experience in solving comparable problems, and transfer to new situations is minimal. That is, while the student is not told how to solve the problem, the stimulus is such that selection of an appropriate procedure is almost automatic. Exercises assessing routine application do not vary much from textbook problems. An exercise might require, for example, the solution of a standard problem on proportion, the demonstration that two geometric figures are congruent, or an estimate of the amount of carpet needed for a room.

Understanding/Comprehension

Mathematical understanding, or comprehension, refers to the interpretation and elaboration of underlying concepts, assumptions, relationships, and the like. These underpinnings may be as elementary as the concept of a fraction or as sophisticated as the concept of a deductive system. Understanding does not rely on memory alone, but also includes the association of ideas and the perception of relationships.

Exercises assessing understanding/comprehension may require the student to identify an example (or something that is not an example) of a concept, to recognize when a particular technique may (or may not) be helpful, to give an explanation, or to translate from one mode of expression to another. For example, a student may be given partial information and be asked to identify the additional information needed in order to solve a routine problem.

Process Area: Skills

Mathematical skill refers to straightforward, routine manipulation and relies on standard procedures that lead directly to answers. Exercises assessing mathematical skill assume that the required procedure has been learned and practiced. They do not require the student to decide which procedure to use or to apply the procedure to a new situation. Such exercises aim at measuring proficiency in carrying out a procedure rather than the understanding of how or why it works.

Mathematical skill is assessed by exercises that require the performance of specific tasks such as making measurements, multiplying two fractions, performing mental computations, graphing a linear equation, or reading a table.

Process Area: Knowledge

Mathematical knowledge refers to both the recall and recognition of mathematical content as expressed in words, symbols, or figures. Mathematical knowledge as described for this assessment relies, for the most part, on memory; it does not ordinarily require any more complex mental processes.

Exercises that assess mathematical knowledge require that a student recall or recognize one or more items of information. Exercises involving recall might ask for a multiplication fact, such as the product of five and two, or for the statement of a mathematical relation such as the law of cosines. An exercise involving recognition might present several symbols and ask which symbol means "parallel."

The following are descriptions provided in NAEP documents on the skills covered by the exercises in each *science* subtest. Exercises could be classified according to the *cognitive processes* required to deal with science content at different levels of complexity. The NAEP committee defined three generic categories -- knows, uses, and integrates -- and based the following descriptions of these categories on cognitive theory that defines three types of knowledge, each of which has a different function in problem-solving.

Knows: These exercises test primarily *factual knowledge*. Successful performance depends on the ability to recall specific facts, concepts, principles, and methods of science; to show familiarity with scientific terminology; to recognize these basic ideas in a different context; and to translate information into other words or another format. This category generally involves a *one-step cognitive process*.

Uses: These exercises test the ability to combine factual knowledge with rules, formulas, and algorithms for a specified purpose. Successful performance depends on the ability to apply basic scientific facts and principles to concrete and/or unfamiliar situations; to interpret information or data using the basic ideas of the natural sciences; and to recognize relationships of concepts, facts, and principles to phenomena observed and data collected. This category generally involves a *two-step cognitive process*.

Integrates: These exercises test the ability to organize the component processes of problem solving and learning for the attainment of more complex goals. Successful performance depends on the ability to analyze a problem in a manner consistent with the body of scientific concepts and principles, to organize a series of logical steps, to draw conclusions on the basis of available data, to evaluate the best procedure under specified conditions, and to employ other higher-order skills needed for reaching the solution to a problem.

This category generally involves *multi-step cognitive process*. In particular, it requires such mental processes as generalizing; hypothesizing; interpolating and extrapolating; reasoning by analogy, induction and deduction; and synthesizing and modeling.

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Table 1

Average Seventh Grade Student Test Score Performance on Mathematics and Science Subtests of Different Levels of Cognitive Complexity by Sex (Source 1985-86 National Assessment of Educational Progress)

	Females	*Males*	*Total*
Science knows test (low complexity)	.430	.453	.442
Science uses test (medium complexity)	.402	.417	.409
Science integrates test (high complexity)	.349	.362	.356
Math skills test (lower complexity)	.422	.398	.410
Math knowledge test (lower complexity)	.371	.365	.368
Math routine application text (lower complexity)	.287	.275	.281
Math understanding test (higher complexity)	.266	.273	.270
Math problem solving/reasoning (higher complexity)	.260	.268	.264

Table 2

Sex Differences in Seventh Grade Student Test Score Performance on Mathematics and Science Subtests of Different Levels of Cognitive Complexity, with Controls on Age Differences (positive values indicate higher male scores)

	Sex Difference (b=r)	Sex Difference Controlling for Age (b)
Science knows test (low complexity)	.029	.048
Science uses test (medium complexity)	.039	.057
Science integrates tests (high complexity)	.046	.067
Math skills test (lower complexity)	-.049	-.024
Math knowledge tests (lower complexity)	-.010	.011
Math routine application test (lower complexity)	-.025	-.001
Math understanding test (higher complexity)	.017	.041
Math problem solving/reasoning test (higher complexity)	.015	.030

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b = standardized regression coefficient

r = zero-order correlation

Table 3

PARTITIONING OF VARIANCE IN SCIENCE SUBTEST PERFORMANCE AMONG THREE FACTORS -- (1) USE OF SCIENCE EXPERIMENTS IN INSTRUCTION (7 VARIABLES), (2) SPECIALIZED SCIENCE TEACHER (8 VARIABLES), AND (3) STUDENT BACKGROUND AND SCHOOL DEMOGRAPHY (11 VARIABLES).

Science Subtest

Variance component	"Integrates" (High complexity)	"Uses" (Medium complexity)	"Knows" (High complexity)
Use of Experiments (Total R)	.01038	.00716	.00565
Speciali[illegible]ed Teacher (Total R)	.01045	.01061	.01147
Student Background (Total R)	.09011	.11048	.09690
Use of Experiments (Unique % variance)	.00951	.00726	.00352
Specialized Teacher (Unique % variance)	.00686	.00652	.00734
Student Background (Unique % variance)	.08227	.09489	.09068
Total R (all 3 Factors)	.10389	.12048	.10756

Table 4

PARTITIONING OF VARIANCE IN MATH SUBTEST PERFORMANCE AMONG THREE FACTORS -- (1) USE OF CALCULATORS IN INSTRUCTION (4 VARIABLES), (2) SPECIALIZED MATH TEACHER (8 VARIABLES), AND (3) STUDENT BACKGROUND AND SCHOOL DEMOGRAPHY (11 VARIABLES).

Mathematics Subtest

Variance Component	"Skills" (Low Complexity)	"Knowledge" (Low Complexity)	"Rout. Appl." (Low Complexity)	"Under-standing" (High)	"Problem Solving" (High)
Calculators (R)	(.002)	(.005)	(.001)	(.006)	(.002)
Specialized Teachers (R)	.029	.038	.035	016	.009
Student Background (R)	.128	.144	.149	.109	.053
Calculators (Unique % variance)	.005	.009	.004	.006	.002
Specialized Teachers (Unique % variance)	.025	.031	.030	.018	.009
Student Background (Unique % variance)	.123	.134	.142	.145	.052
Total R (all 3 Factors)	.156	.179	.180	.123	.063