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ABSTRACT

Linking teacher treatment to student impact is not as straightforward as it may seem initially. The difficulties in measuring the impact on students are illustrated in this discussion of the Ohio Statewide Systemic Initiative (SSI). Since the inception of the SSI, the external evaluators had planned to use data from the state's proficiency tests for ninth grade as one measure of student impact, but they encountered numerous difficulties, largely because the tests had not been completely developed. A pilot test of the SSI mathematics test in 1994 indicated the advisability of using a revised version of the pilot test in 1995. The revised Mathematics Discovery Test was administered to 1,070 students whose teachers had participated in the Project Discovery professional development for use of the SSI and 682 students whose teachers had not participated in Project Discovery. A Science Discovery Test was also administered to 1,127 Discovry students and 789 non-Discovery students. Results of these two tests show the superior performance of the students of Discovery teachers. Experience in the test development process demonstrates the importance of teacher involvement in the development of tests designed to provide student impact data. Key stakeholders must be involved to ensure the appropriate alignment of the instrument. (Contains two figures and five tables.) (SLD)

Measuring Student Impact

in the

Context of Statewide Education Reform

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Overview

As the external evaluators of Ohio's Statewide Systemic Initiative (SSI), we had readily obtained data from classroom observations, teacher surveys, and interviews with teachers and administrators that indicate that the SSI is having a positive impact on students; however, we realized that more systematic data on student performance would be an essential measure in demonstrating the project's success. Upon encountering numerous obstacles in our efforts to utilize secondary data (collected by the state as part of its statewide testing program), we moved toward a process of creating mathematics and science tests in which skills expected to be impacted by the SSI would be measured. Unplanned and unanticipated were the benefits to the SSI itself through the inclusion of numerous stakeholders from the state's education community in the test development process and the associated discussions of appropriate outcomes.

There are currently 25 SSI states funded by the National Science Foundation and supplemented by various matching funds from each state. The SSI states were given the mission of implementing systemic reform in mathematics and science education across their entire state. An SSI's impact on students is, of course, one of the key pieces in determining the SSI's success. For most SSIs, including the one covered in this report, the major treatment is professional development for teachers.

Linking teacher treatment to student impact is not as straightforward as it may initially seem. Questions abound: what is the intensity of teacher treatment needed to have an impact on students? How long after the treatment would we expect to see changes in student skills associated with the professional development? What group of students would be an appropriate control group to the experimental SSI group? What test data are available that would provide an acceptable measure of student impact? Do we need to develop tests that would specifically measure areas of change targeted by the SSI? If so, what are the essential criteria by which the design of such a test needs to be guided?

Obstacles and Alternatives

Ohio has a statewide testing system in which ninth graders are required to pass competency tests in mathematics, reading, and citizenship. A science section is in the process of being developed. Since the onset of the SSI, we had planned to use data from the statewide ninth grade mathematics proficiency test as one measure of student impact. However, we encountered numerous obstacles in our efforts to use the statewide data. We were especially concerned about the availability of proficiency data in a timely fashion and of being able to obtain results on individual test items. Furthermore, in Ohio's SSI, known as "Project Discovery, "the teacher professional development program consisted of six week intensive "summer institutes" in inquiry instruction in one of three disciplines (mathematics, physics, and life science). Because the first step in Discovery was to prepare a cadre of people who could deliver these institutes, the number of participants in the first year (1992) was less than 100. Although by the third summer (1994) the total number of teacher participants was approximately 750, the relatively small number of SSI teachers statewide complicated our ability to use secondary databases such as statewide proficiency test results. At a March 1994 evaluation meeting, project staff and the evaluators made a commitment to developing a mathematics test that would allow analysis of student performance on specific test items and which could be administered as soon as possible.

Earlier in the year, we had obtained the National Assessment of Educational Progress (NAEP) publicly released eighth grade mathematics and science test items (from NAEP tests administered in 1986, 1990, and 1992). In April 1994, the Ohio SSI formed a task force composed of university-level mathematics faculty, members of the SSI's regional mathematics Academic Leadership Teams (composed of school teachers and "Scientist/Mathematician Educators"), and other SSI project staff. This task force drew from the NAEP items in developing an instrument specifically designed to measure students' abilities in the mathematics and science content and higher-order thinking and problem solving skills reflected in the inquiry and constructivist methods of teaching exemplified in Project Discovery professional development training. Because NAEP uses a complex matrix sampling of students, for which all items are not made publicly available, the Discovery test results cannot be benchmarked against National NAEP results.

Pilot Test Results (Spring 1994)

In late April through May 1994, project staff in two of the SSI regions asked SSI teachers and those selected for the upcoming 1994 summer institutes (the control group) to administer the SSI Mathematics Test to their eighth grade mathematics classes. A total of 21 teachers, 10 SSI teachers and 11 non-SSI teachers, volunteered to administer the test to students. A total of 873 SSI students and 718 non-SSI students took the test.

Although we recognize the limitations of the pilot testing research design (including the small sample of teachers and the non-random nature of the selection process) the pilot test effort provided useful preliminary information. In the questionnaire accompanying the pilot test, students confirmed that SSI teachers were using teaching practices modelled in the summer institutes, such as cooperative groups. Furthermore, SSI students' performance on the test was consistent with the prediction that inquiry-based instruction would have a positive influence on problem-solving and conceptual thinking skills. Finally, the pilot test results convinced us of the value of implementing such a test in 1995 with a larger number of randomly selected teachers.

Spring 1995 Results

In conjunction with the evaluators, the mathematics test task force revised the pilot test. In an effort to make the assessment more "inquiry-oriented," the new test instructed students to explain several of their answers. The 1995 Mathematics Discovery Test consisted of 14 items and the 1995 Discovery Science Test contained 29 items, including multiple-choice items, items involving tables and graphs, and open-ended questions. In addition, we expanded testing to a larger number of teachers and used a stratified random sample in selecting SSI and non-SSI teachers. Since we were especially interested in the impact of the SSI on "high risk" students, we oversampled teachers in urban, high minority schools.

In the spring of 1995, 2,197 students whose teachers underwent Project Discovery professional development and 1,471 students whose teachers received no Project Discovery treatment were tested with a battery of mathematics and science items developed by the National Assessment of Educational Progress (NAEP).

Distinct patterns emerged about the students of teachers who participated in the Discovery program when compared to those who did not. These patterns were similar in both mathematics and science. First, on both close-ended and open-ended questions, Discovery students significantly outperformed non-Discovery students after controlling for sample differences. Second, except for boys in mathematics, all gender and ethnic groups whose teachers received the Discovery treatment performed significantly better than comparable students of teachers who did not. Third, student attitudes about their subject were similar for both Discovery students and non-Discovery students. Fourth, Discovery students reported participating in more hands-on and inquiry based activities than did non-Discovery students.

The Teacher Sample

The sample of teachers who were asked to give their students the Discovery Tests were selected randomly from both teachers who had participated in Project Discovery (the "treatment" group, also called Discovery teachers) and from those identified as the next cohort of Project Discovery, but not yet treated (the "control" group, also called non-Discovery teachers). The treatment sample was selected from those teachers who had received the Discovery professional development between 1992 and 1994.

Before randomly selecting the sample of treated teachers, the population was stratified between those schools with greater and less than 40 percent minority student body. To increase the sample size, 7th grade teachers in high minority schools were added to the sample. The randomly selected sample of treated teachers contained 80 mathematics teachers and 80 science teachers. To select the control group, regional directors were asked to compile lists of teachers, their subject (mathematics or science), grade (7 or 8), and community type (city/non-city) who would be participating in 1995 in their region. They were then directed to request participation from a specified number of teachers based on subject, grade, and community type. In all, the regions were asked to select 68 control teachers in each of mathematics and science for participation.

In mathematics, 46 Discovery teachers returned student tests, for a response rate of 58 percent, while 35 non-Discovery teachers returned student tests, for a response rate of 51 percent. In science, 51 Discovery teachers returned their student tests, for a response rate of 64 percent, while 35 non-Discovery teachers responded, for a response rate of 51 percent. Although we recognize the limitations of the research design (including mediocre response rates and possible response bias), the results provide useful preliminary information.

Student Demographics

From the classes that participated in the study, 1,070 Discovery students and 682 non-Discovery students took the mathematics test, and 1,127 Discovery students and 789 non-Discovery students took the science test. Table 1 provides demographic information about the students who took the mathematics and science Discovery tests. The two samples (students of Discovery teachers and students of non-Discovery teachers) are comparable in terms of gender, but differ in both ethnicity and community type. In both subjects, a significantly greater proportion of the non-Discovery sample were white, while a greater proportion of the Discovery sample were minorities. In the mathematics sample, a significantly larger percent of the students of teachers who underwent the Discovery treatment were from rural and urban areas, while a larger percent of the non-Discovery students were suburban. In the science sample, the Discovery group had larger proportions of students from schools in small towns and large cities than did the non-Discovery sample.

The mathematics sample had a slightly larger percent of students of Discovery teachers in 7th grade mathematics. The proportion of 8th graders (which includes students responding that they were enrolled in 8th grade mathematics, pre-algebra, and algebra) was similar in both samples. There was a greater proportion of students in pre-algebra and algebra classes in the mathematics Discovery sample. The science non-Discovery sample contained a larger proportion of 8th grade science students, as compared to the Discovery sample.

Tables 2 and 3 show attitudinal data, and activities of the students who took the mathematics and science Discovery test of selected NAEP items. Overall, Discovery and non-Discovery students reported similar attitudes towards, and opinions about, mathematics and science. However, there were several important and significant differences, in both mathematics and science, in the activities that students of Discovery teachers experienced. Discovery students reported more work in small groups, working with hands-on activities, and using language to convey both mathematics and science. Discovery students also reported spending less time working with textbooks and taking mathematics tests.

Impact on Student Performance: Analysis of Close-Ended Student Responses

Given our interest in examining the impact on student performance of teacher participation in the Discovery program, and relationships between participation, student gender and ethnicity and student performance, we constructed regression models which included teacher participation in Discovery, student gender, and student ethnicity as variables of interest. We also included covariates controlling for differences in community types of the samples, the proportion of students in a school receiving free and reduced lunch, and the grade level of students. Tables 4 and 5 shows results of these regression analyses for science and mathematics, respectively.

The science model reveals several important findings about the effectiveness of project Discovery. First, students of Discovery participants scored significantly higher (t-value = 2.7, $p<.01$) than did students of non-participants after controlling for student and community factors. Second, after holding all other things equal, girls performed significantly better than boys (t-value = 2.5, $p<.05$). Third, both white students (t-value = 9.3, $p<.001$) and students of other ethnicities (t-value = 4.8, $p<.001$) performed significantly better than black students. Not surprisingly, eighth graders outperformed seventh graders (t-value = 4.7, $p<.001$) and there was a negative association between student performance on the Discovery test and poverty (as measured by percentage of students in the school receiving lunch assistance). Surprisingly, urban students significantly outperformed both their small city and suburban counterparts. This may be related to the different proportions of students of different ethnicities and from different communities in the sample.

The mathematics model uncovers some similar details but includes differences as well. Foremost, students of Discovery participants outperformed students of non-participants after controlling for student and community variables. However, on the mathematics Discovery test, after holding constant all other factors (including participation) boys significantly outperformed girls (t-value = 2.8, $p<.01$). The model also reveals an interaction between gender and participation, with girls of Project Discovery teachers performing significantly better than girls of non-Project Discovery teachers, while there were no significant differences between the boys of participants and those of non-participants. As on the science test, both white students and those of other ethnicities significantly outperformed black students. However, on the mathematics Discovery test, urban students performed significantly lower than did students from other communities.

One way to get a better grasp of these regression data is to examine the predicted performance of a prototypical student. Figures 1 and 2 show the predicted performance of students of different genders and ethnicities of both participating and non-participating teachers in Project Discovery. These predicted percentage correct scores are for eighth grade students in schools with the average percentage of students receiving lunch assistance (31 percent in the science sample and 32 percent in the mathematics sample), from small towns (where the largest percentage of students in the science sample reside). For example, an eighth grade white female from a small town school with the average percentage of its students receiving lunch assistance whose teacher participated in Project Discovery would be predicted to get 62.34 percent correct on the Discovery test, while a comparable student whose teacher did not receive Project Discovery training would be predicted to score 59.14 percent on the Discovery test.

Figure 1, which depicts the science performance of the prototypical eighth grade student in a small town school with the average percentage of students receiving lunch assistance, illustrates four important findings about Project Discovery's impact on student achievement after controlling for school, community, and grade level differences. First, on average those students of teachers who received the Project Discovery treatment performed significantly better than those students of teachers who did not receive the Project Discovery treatment. Second, on average, girls outperformed boys on the science Discovery test. Third, white students of both Discovery and non-Discovery teachers significantly outperformed their black counterparts. Finally, and perhaps most importantly, all students of Discovery teachers - blacks, whites, boys, and girls - performed better than comparable students of non-Discovery teachers.

Figure 2 shows the mathematics performance of the prototypical eighth grade student in a small town school with the average percentage of students receiving lunch assistance. This figure illustrates that the significant differences in performance between students of Discovery and non-Discovery teachers is due to the high performance of girls of Discovery teachers when compared to their non-Discovery counterparts, while boys' performance is relatively flat. As on the science Discovery test, whites outperformed blacks, but both black boys and black girls whose teachers had participated in Discovery performed significantly better than their non-Discovery peers.

Impact on Student Performance: Analysis of Open-Ended Student Responses

Each student Discovery test included 2-3 open-ended items (three in science, two in mathematics) where the students were asked to write an explanation to convince a fellow-student of their knowledge. A stratified random sample of 32 classes (eight Discovery, eight non-Discovery in each of science and mathematics) was selected based upon the grade-level and urbanicity of the classes. Each of the eight regions was sent the open-ended responses from four classes (two science, two mathematics). Each region was instructed to convene teams of science and mathematics experts to rate each open-ended student response separately, and than reconcile their ratings. Ratings were based on a rubric that scaled the student responses from 0 (No attempt at task or nonsense response) to 4 (excellent response; accurate and well-explained). All regions completed and returned the mathematics packets, while seven of the eight science packets were returned.

The ratings of student responses for the three open-ended science items and the two open-ended mathematics items were cumulated to arrive at a total point score for mathematics and science. Table 5 shows the means and standard deviations for all Discovery and non-Discovery students' open-ended questions as well as t-tests for differences between these means. These statistics are also disaggregated in table 5 by gender and ethnicity. In both science (t-value 5.05, $p <= .001$) and mathematics (t-value 4.15, $p <= .001$) the students of Discovery teachers performed significantly better than their non-Discovery counterparts. Discovery students of all gender and ethnic groups, except for boys in mathematics, performed significantly better on the open-ended questions than did their non-Discovery counterparts.

Conclusion

Our experience provides an example of how student impact data were collected for a statewide reform effort in which the involvement of the larger education community became an important factor. The process of bringing together such a multifaceted group of teachers, project staff, state department of education representatives, university professors, and industry-based mathematicians and scientists resulted in tests that served multiple purposes. The mathematics and science test task forces designed tests that were consistent with the aims of the project, would provide student impact data that would meet the needs of the evaluators, and would also provide additional formative feedback to project staff (especially the regional Academic Leadership Teams who had the most direct contact with teachers and students). Although the evaluators were responsible for ensuring that the tests were developed, implemented, and processed, the discipline-specific task force members developed the tests, ensured that test packets were distributed to teachers, and graded the open-ended items. Having shared responsibility resulted in a stronger endorsement of the testing process than would have been possible had the testing effort been solely the evaluators' concern. Furthermore, the collaborative process that ensued was confirmation that the SSI was successfully promoting collaboration among a wide range of stakeholders.

Important lessons we have learned through our efforts to measure student impact in the context of statewide reform are:

- We faced numerous difficulties using existing state test data, including:

    1) We could not readily identify and disaggregate treated teachers (essentially a unit of analysis problem).

    2) Since there were not teacher identifiers or student identifiers on the state database, we would have to access data from each district for a specified sample of students (a very labor intensive task).

    3) State test data results were in terms of an overall test score (Pass/Fail) rather than individual item results. Such a single score is of limited value in understanding student impact.

- Key stakeholders must be intimately involved in the test development process to ensure that the instrument is appropriately aligned with the vision of the initiative and to provide assistance with test administration and processing, especially if there are open-ended or performance task items.

- The approach to student impact data is state specific. Although the Ohio SSI has found the NAEP public-release items to provide very useful and informative data, our current work with the New Jersey SSI indicates that such an approach is not necessarily transferable to other states. Since the New Jersey SSI vision includes a very strong commitment to performance-based assessment, the use of multiple-choice items is viewed as sending an inappropriate message to teachers. Consequently, in an effort to design tests that are consistent with the state's goals, we are in the process of identifying performance-based tasks that we would administer to students in New Jersey.

Table 1

Sample Sizes and Demographic characteristics of students of mathematics and science teachers who attended Discovery training and those not yet receiving Discovery training.

	SCIENCE		MATHEMATICS	
	Non-Discovery	Discovery	Non-Discovery	Discovery
All Students	788	1,083	680	1,065
Gender				
Female	52%	56%	54%	55%
Male	48%	44%	46%	45%
Race/Ethnicity *				
White	75%	56%	77%	67%
Black	19%	32%	16%	24%
Hispanic	2%	6%	2%	4%
Amer. Indian/Alaskan Native	2%	3%	3%	3%
Asian/Pacific Islander	2%	2%	2%	2%
School Location *				
Rural	28%	26%	28%	51%
Small Town	18%	37%	26%	10%
Suburban	37%	11%	36%	23%
Large City	18%	26%	10%	16%

* Significant differences between samples of Discovery and Non-Discovery students in both mathematics and science (chi-square $p<.05$).

Table 2

Types of science classes, classroom activities, and attitudes of students who took the science Discovery test.

	Non-Discovery	Discovery
Type of Science Class *		
Not taking science this year	<1%	<1%
Seventh-grade science	16%	33%
Eighth-grade science	79%	62%
Other science class	4%	4%
Expected 9th grade science *		
Will not take science	3%	1%
General science	18%	14%
Biology or Life Science	30%	34%
Physical Science or Physics	15%	13%
Chemistry	6%	10%
Other science class	10%	3%
I don't know	18%	27%
Do the following at least once a week		
Problems from textbooks *	59%	52%
Work in small groups *	36%	70%
Use a calculator	21%	21%
Use a computer	13%	10%
Take science tests	44%	44%
Do the following at all		
Do lab activities *	74%	87%
Write a few sentences about how solved science problem *	59%	77%
Make up science problems for others to solve *	19%	24%
Write reports or do projects *	55%	64%
Agreement with following items		
I like science	60%	59%
I am good at science	57%	54%
If I had a choice, I would not study any more science	24%	25%
I understand most of what goes on in science class	74%	72%
science is more for boys than girls	10%	7%
Learning science is mostly memorizing facts	32%	30%
Almost all people use science in their jobs	49%	45%
science is useful for solving everyday problems	53%	52%

* Significant differences between samples of Discovery and Non-Discovery students (chi-square p<.05).

Table 3

Types of mathematics classes, classroom activities, and attitudes of students who took the mathematics Discovery test.

	Non- Discovery	Discovery
Type of Mathematics Class *		
Not a mathematics class	<1%	<1%
Seventh grade math	17%	25%
Eighth grade mathematics	51%	30%
Pre-algebra	11%	23%
Algebra	16%	21%
Other mathematics class	4%	1%
Expected 9th grade mathematics *		
Will not take math	1%	<1%
Basic, general, business	14%	8%
Pre-Algebra	13%	12%
Algebra I	28%	34%
Geometry	18%	20%
Other mathematics class	8%	6%
I don't know	18%	19%
Do the following at least once a week		
Problems from textbooks *	82%	77%
Work in small groups *	46%	55%
Use a calculator *	69%	75%
Use a computer	14%	14%
Take mathematics tests *	50%	45%
Do the following at all		
Work with hands-on manipulatives *	71%	77%
Write a few sentences about how solved mathematics problem *	35%	51%
Make up mathematics problems for others to solve *	24%	28%
Write reports or do projects *	22%	40%
Agreement with following items		
I like mathematics	57%	56%
I am good at mathematics	60%	57%
If I had a choice, I would not study any more math	21%	19%
I understand most of what goes on in math class	75%	74%
Mathematics is more for boys than girls	5%	4%
Learning mathematics is mostly memorizing facts	44%	41%
Almost all people use mathematics in their jobs	88%	86%
Mathematics is useful for solving everyday problems	79%	78%

* Significant differences between samples of Discovery and Non-Discovery students (chi-square $p<.05$).

Table 4

Full Regression Model showing coefficients and standard errors for student science performance. (n = 1144)

Variable	Coefficient (Standard Error)
Intercept	42.27 *** (2.42)
Participation in Discovery	3.203 ** (1.18)
Percent of Student in Class Receiving Free/Reduced Lunch	-.10 *** (.03)
Eighth Grader	6.10 *** (1.30)
White	15.44 *** (1.65)
Other Ethnicity	11.25 *** (2.33)
Female	2.75 ** (1.10)
Rural	-2.32 (1.60)
Town/Small City	-4.38 ** (1.66)
Suburb	-4.22 * (1.74)
R^2	.19

*** $p \leq .001$ ** $p \leq .01$ * $p \leq .05$ ~ $p \leq .10$

Table 4

Full Regression Model showing coefficients and standard errors for student mathematics performance. (n = 1230)

Variable	Coefficient (Standard Error)
Intercept	45.15 *** (3.24)
Participation in Discovery	1.99 (1.78)
Percent of Student in Class Receiving Free/Reduced Lunch	-.21 *** (.03)
Eighth Grader	3.87 ** (1.33)
White	11.94 *** (1.82)
Other Ethnicity	6.07 ** (2.32)
Female	-5.03 ** (1.79)
Rural	6.26 ** (2.00)
Town/Small City	9.97 *** (2.10)
Suburb	13.36 *** (1.92)
White X Participation Interaction	4.93 * (2.31)
R^2	.25

*** $p \leq .001$ ** $p \leq .01$ * $p \leq .05$ ~ $p \leq .10$

Figure 1

Prototypical plot of predicted science performance for eighth grade student in a small town school with the average percentage of students receiving lunch assistance.

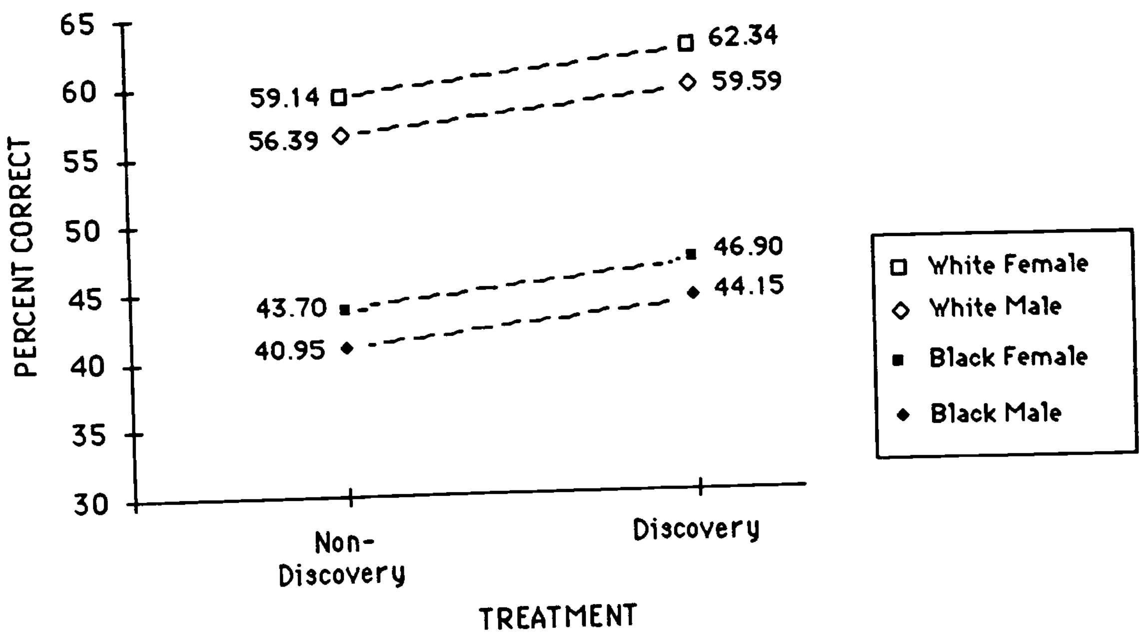

Figure 2

Prototypical plot of predicted mathematics performance for eighth grade student in a small town school with the average percentage of students receiving lunch assistance.

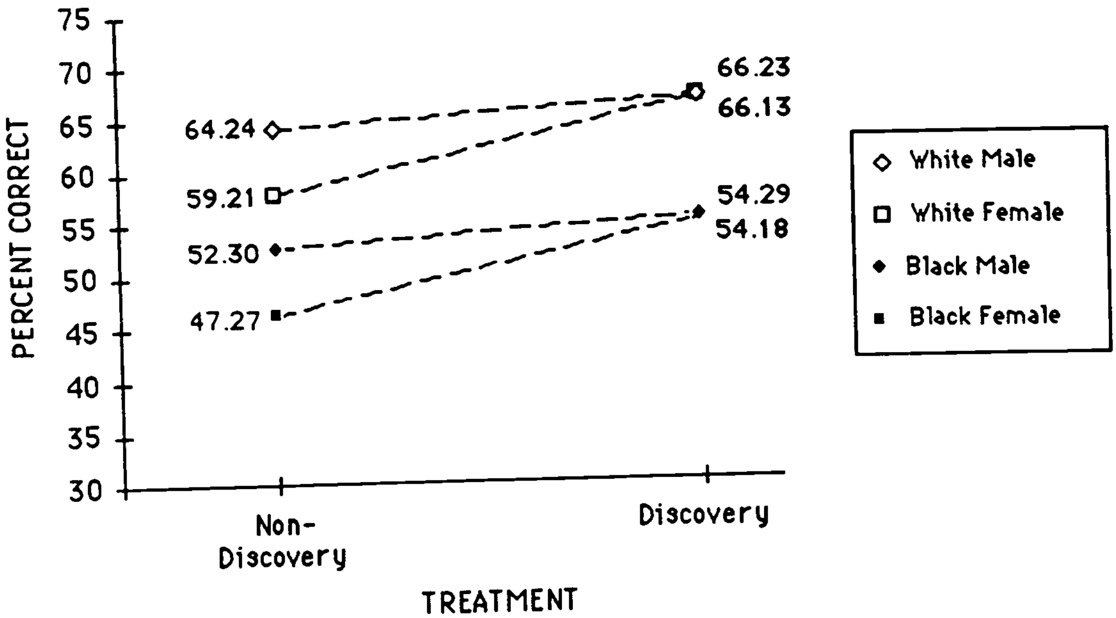

Table 5

Means, standard deviations, and t-tests for Discovery and non-Discovery student responses on open-ended science and mathematics questions.

	Discovery Mean (Stand. Dev)	Non-Discovery Mean (Stand. Dev)	T-Value	d.f.
SCIENCE				
All Students (n = 224)	5.79 (2.78)	3.83 (2.99)	5.05 ***	224
Girls (n = 134)	6.01 (2.83)	3.52 (2.90)	4.88 ***	132
Boys (n = 92)	5.38 (2.68)	4.18 (3.08)	2.01 *	90
Blacks (n = 81)	6.42 (2.88)	4.18 (3.24)	3.29 **	79
Whites (n = 123)	5.62 (2.80)	3.58 (2.77)	4.02 ***	121
MATHEMATICS				
All Students (n = 247)	4.96 (2.33)	3.65 (2.59)	4.15 ***	245
Girls (n = 151)	5.08 (2.14)	3.51 (2.61)	4.07 ***	149
Boys (n = 95)	4.72 (2.58)	3.90 (2.56)	1.53	93
Blacks (n = 48)	2.80 (2.39)	4.46 (1.81)	2.27 *	46
Whites (n = 184)	5.02 (2.39)	4.02 (2.59)	2.61 **	182

*** $p \leq .001$ ** $p \leq .01$ * $p \leq .05$ ~ $p \leq .10$

AERA April 8-12, 1996

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