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Effective Primary Level Science Teaching in the Philippines

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Frequent group work, frequent testing, and laboratory teaching improved the achievement of fifth-grade science students in the Philippines. But what influenced a teacher's decision to adopt these practices?

Early studies of educational achievement in developing countries emphasized the effects of material inputs (such as textbooks) over teaching practices and classroom organization. Lockheed, Fonacier, and Bianchi examined how five teaching practices affected the achievements of fifth-grade students in the Philippines — and what affected teachers' decisions to use effective teaching practices.

With school, teacher, and classroom characteristics held constant, achievement was higher for students whose teachers used three teaching practices that show promise for applications in developing countries because they are effective, low-cost, or cost-effective:

- Frequent tests and quizzes.

- Small group instruction, including peer tutoring.

- Teaching through laboratory work, particularly for science.

Group work and testing were twice as effective as laboratory work. Students whose teachers used group work in science scored 40 percent of a standard deviation higher than students whose teachers did not. Frequent testing raised achievement 25 percent of a standard deviation. And laboratory use raised it 15 percent.

Teacher's decisions about whether to test students frequently were unrelated to their prior education or experience. Group work was used more often by younger teachers, suggesting that recent teacher training may have emphasized group work to offset the difficult[illegible] of larger classrooms. Teachers who used laboratories also read more about teaching and reported more frequent participation in in-service training. But in general teachers' decisions about teaching practices were unrelated to their prior education or experience — suggesting that school-level management may be more important in encouraging effective teaching than preservice education and training.

[Using two-stage least squares regression techniques, the authors analyzed data from 419 classrooms that participated in the IEA International Science Study.]

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Early models of educational achievement in developing countries examined the learning effects of school resources, emphasizing such material and non-material inputs as per-pupil expenditures, teacher qualifications, textbooks and amount of instructional time (see Heyneman and Loxley, 1983 and Fuller, 1987, for reviews). In all cases, emphasis was placed on improving achievement by increasing at the margin the resources available to students in low income countries. The most consistently replicated findings link achievement to availability of instructional materials (Heyneman, Farrell & Sepulveda-Stuardo, 1981) and the quantity and pacing of instruction (Brophy and Good, 1986; Denhan and Lieberman, 1980; Brown and Saks, 1987; Levin and Tsang, 1987).

A major shortcoming of the early research was its failure to consider specific teaching practice and classroom organizational processes required to produce learning from these inputs. Research in industrialized countries, by comparison, has provided a rich body of information regarding the relative effectiveness of a variety of classroom process variables. Three teaching practices that show promise for application in developing countries because of demonstrated effectiveness, low cost or cost-effectiveness are: (a) close monitoring and evaluation of student performance through questioning and reacting to student performance as well as through tests and quizzes (Brophy and Good, 1986; Kulik and Kulik, 1988), (b) small group instruction, including peer tutoring (Allen, 1976; Levin, Glass and Meister, 1984; Slavin, 1980; Sharan, 1980), and (c) particularly for science, teaching through practical activities (Bredderman, 1983).

The purpose of this paper is to extend the literature on school effects on educational achievement in developing countries by examining the effects of classroom teaching practices in conjunction with effects of material and non-material inputs on science achievement of grade five students in the Philippines.

The Philippines provides an interesting case for two reasons. First, the primary education system has had sufficient capacity to accommodate the entire primary age population for over twenty-five years, with the consequence that national policy has turned toward improving school quality. Second, educational reforms for quality improvement, implemented in the early 1980's, were designed to affect directly the teaching of science. In the early 1980's, new science textbooks were provided for all elementary school students, lowering the student/textbook ratio from 8:1 to 1.5:1 and enabling teachers to use textbooks for their teaching. The new textbooks deemphasized rote memorization of facts and stressed learning science through enquiry methods. Along with books, science kits were developed and distributed to elementary teachers to encourage the use of practical activities. Teachers were given training in the use of the new materials. However, because national implementation of these reforms was not complete in 1983-84, at the time the data analyzed in this paper were collected, wide variability in the availability of the new teaching practices and materials enables an examination of the effects of their use on student science achievement.

The paper is organized as follows. Section I reviews the literature on effective teaching practices in developing countries. Section II describes science teaching in the Philippines at the time of the study, and provides background on the science teaching reform. Section III presents the data and analytic methods, and Section IV presents our results. Section V presents our conclusions and draws policy implications.

Section I: Literature Review

Both educational inputs and education processes contribute to student learning, and both have been studied in developing country contexts. The evidence with respect to learning effects of inputs is much more extensive than that with respect to the effects of processes. This section reviews the research evidence from developing countries regarding achievement effects of three material and non-material inputs: instructional time and textbooks (chosen for known effectiveness), and laboratories (chosen for particular relevance for science teaching). It also reviews the research evidence from developed countries regarding three teaching practices: use of small groups for instruction, frequent monitoring and evaluation of student performance, and use of practical activities in science instruction.

Effective Inputs

Previous developing country research on factors related to science achievement identified two inputs generally found effective in developing countries (textbooks and time) and one input with specific relevance to science teaching that has been found less effective (laboratories). The bulk of evidence regarding the effectiveness of these inputs comes from the first (1970-71) International Association for the Evaluation of Educational Achievement (IEA) science study, which included four developing countries (India, Thailand, Iran and Chile) and the Programa de Estudos Conjuntos de Integracao Economica da America Latina (ECIEL) survey of science achievement in Latin America (Bolivia, Brazil, Colombia, Mexico, Paraguay, Peru). A reanalysis of data from these studies found that school and classroom level variables accounted for significant proportions of student-level variance in science achievement in each of the countries (Heyneman and Loxley, 1983). Significant effects were found for time and instructional materials, but not for laboratory facilities.

Time. The amount of instructional time available for teachers and students has been found consistently related to achievement in both developed and developing countries. In developing countries, Heyneman and Loxley (1983) found several time use variables associated with science achievement: student time spent reading the science text in class (India, Iran, Thailand, Chile), time on homework (India, Thailand and Iran), and hours of science instruction (India, Thailand and Iran). Arriagada (1981, 1983), however, found conflicting results for teaching time in Colombia and

Peru. In Colombia, instructional time was positively related to science achievement, while in Peru, teacher time spent explaining and the number of class hours per week on science were negatively related to student achievement.

Textbooks and instructional materials. For the past decade, researchers have documented the effect of textbooks on student achievement in developing countries. A review of this research notes that of 18 correlational studies of textbook effects on student learning, 15 (83%) report statistically significant positive results (Heyneman, Farrell, & Sepulveda-Stuardo, 1981). Two studies with experimental assignment of students to textbook conditions also report significant effects of textbooks on achievement (Heyneman, Jamison & Montenegro, 1984; Jamison, Searle, Galda & Heyneman, 1981). A recent study of textbook effects on mathematics achievement in Thailand indicates that textbooks affect achievement by substituting for higher levels of teacher education and by delivering a more coherently organized curriculum (Lockheed, Vail & Fuller, 1986). The effects of instructional materials on science achievement have been studied extensively. Teacher and student use of textbooks were positively related to science achievement in India and Paraguay; use of individual reading materials by teacher affected student achievement in India, and frequent use of audio visual materials affected science achievement in Iran and Chile (Heyneman and Loxley, 1983). In two related studies, Arriagada (1981, 1983) found positive effects for teachers use of instructional materials (audio-visual aids in Colombia and "individual aids" in Peru).

Laboratories. Recent definitions of "scientific literacy" emphasize the acquisition of a scientific world view that values, among other things, the rational understanding of phenomena and the development of scientific habits of mind (Murnane and Raizen, 1988). Development of these habits is believed to be assisted by laboratory or laboratory-like instruction. Research on the achievement effects of laboratories in developed countries, however, fail to confirm this expectation. An extensive review of laboratory effects (Blosser 1980, cited in Haddad 1986) concludes that there is insufficient evidence to confirm the effects of laboratory work on science learning. Similarly, Hofstein and Lunetta (1982) note that "research has failed to show simplistic relationships between experiences in the laboratory and student learning."

Despite their apparent ineffectiveness, the demand for laboratories for science instruction is great in developing countries. For example, Mundangepfupfu (1985) notes that the requirement for experimental work in the science examinations offered by the Cambridge Examination Syndicate largely results from requests from third world ministries of education and headmasters. Research on the achievement effects of laboratories in developing countries is inconclusive, but tends to follow that from developed countries. In their reanalysis of IEA and ECIEL data, Heyneman and Loxley (1983) found that the number of students in laboratory classes and the time spent in laboratory classrooms or on laboratory work were related to achievement in India, Thailand, Argentina and Iran. However, laboratory use was unrelated to achievement in all six Latin American countries that participated in the ECIEL study (Heyneman and Loxley, 1983).

Effective Processes

Three other classroom organization and teaching process variables that have been found effective in industrialized countries but have been studied only minimally in developing countries are: (a) teacher monitoring and evaluating, including testing, (b) cooperative group work, including peer tutoring, and (c) use of practical activities for science instruction

Evaluation and Testing. Frequent monitoring and evaluation of student performance has been identified as one of the characteristics of effective schools (Purkey and Smith, 1983). The interest in monitoring and evaluation is not new, however. A recent review of the effects of timing of feedback on student learning (Kulik and Kulik, 1988) notes that the first systematic studies of the effects of feedback on student learning was conducted over sixty years ago by Sidney Pressey (1926), who believed that students would learn more quickly if they received immediate feedback on the correctness of their test answers, rather than waiting up to months for their results. Few studies have actually compared immediate feedback with such long delays; most research has compared immediate feedback with delays ranging from a few seconds to a week.

The effects of feedback immediacy on achievement has recently been examined in a review of 53 studies, covering both classroom applied research and experiments (Kulik and Kulik, 1988). In nine of the 11 applied studies reviewed, students achieved more in classrooms where they received immediate rather than delayed feedback from classroom quizzes, with results more consistently positive for adults than for children. Two studies with grade 8 students as subjects reported contradictory findings, one showing a positive effect size of .60 (Paige, 1966) and the other a negative effect size of -.55 (More, 1969). Of the experimental studies reviewed in the same paper, seven dealt with children's learning (paired associates or stimulus discrimination); three studies found delayed feedback superior to immediate feedback (average effect size -.31) and four studies found the converse (average effect size +.74).

Observational studies of teacher behavior and student achievement, however, provide more consistently positive evidence in favor of ongoing monitoring and evaluation effects on student learning (Brophy and Good, 1986).

In developing countries, few studies of the effects of monitoring, evaluation, or feedback have been conducted, but results are consistently positive. For example, Arriagada (1983) found a positive effect for teacher monitoring and evaluations of student achievement; teacher evaluations (progress reports) were positively related to achievement in science in Colombia. Heyneman and Loxley (1983) report that teacher time spent grading tests at school was related to science achievement in Argentina and Colombia, teacher time spent discussing exercises was related to science achievement in Paraguay, and teacher time spent correcting exercises was related to science achievement in Argentina. Lockheed and Komenan (1988) found that teacher time spent monitoring and evaluating student performance was positively related to mathematics achievement in Swaziland.

Small group instruction. Small group instruction takes the form of teacher-led or student-led instructional groups, cooperative learning groups, and peer tutoring (cross-age or same-age). Studies of peer tutoring effects on achievement are consistently positive (Allen, 1976), and peer tutoring has recently been identified as a highly cost-effective teaching practice (Levin, Glass and Meister, 1984). Although observational studies rarely have examined cooperative group effects on achievement (Brophy & Good, 1986), results from experimental studies show strong positive effects (Slavin, 1980; Sharan, 1980).

Practical activities. Research from industrialized countries provides evidence that children's scientific learning is enhanced by activity-based, experimentative, science instruction. A review of 57 studies of the effects of three types of activity-based elementary science programs compared with regular science instruction, found that the overall mean effect size was .52 for science process tests and .16 for tests of science content, with disadvantaged students gaining more than other students from the programs (Bredderman, 1984). The low effect size (.16) for science content indicates that the activity based programs were no different from regular programs in teaching scientific content; they were significantly more effective in teaching scientific literacy, however. Haddad (1986) also notes that practical activities in science teaching seem to be important for elementary school students at the concrete stage of development, and for low ability students in general, who are also more dependent upon concrete experiences for learning.

Purpose

We hypothesize that school and teacher effectiveness in developing countries is determined as much by teaching practices and specific uses of material inputs as it is by the material inputs alone, and that significant efficiencies can be realized by teacher training that emphasizes effective teaching practices. We also hypothesize that material inputs, such as textbooks and laboratories, will be made more effective by complementary teaching practices. Laboratories, for example, will be complemented by classroom organization that permits students to work together in groups. Textbooks will be made more effective by teachers who use textbooks frequently. This paper explores these relationships.

Section II: Philippine Science Education

Overview

The general pattern of pre-university education in the Philippines consists of six years of compulsory elementary school followed by four years of secondary school, although some private schools offer seventh grade and/or kindergarten. Since 1965, gross primary enrollment rates for both boys and girls have exceeded 100% (World Bank, 1988), with 8.7 million elementary students enrolled in 1983-84, the year in which this study was conducted. Ninety-five percent of elementary school students attend public schools.

All public elementary schools are funded by the national government, and all are under the jurisdiction of the Department of Education, Culture and Sports (DECS, formerly Ministry of Education, Culture and Sports) through the Bureau of Elementary Education. In 1983, education's share of the national budget was second only to defense, but the total funding for education was low (1.3% of GNP) and per-pupil expenditures for elementary students averaged only about P453 (Ministry of Education, Culture and Sports and National Science and Technology Authority, 1985).

From the third grade to tenth grade the official medium of instruction is the national language, Pilipino, except for science and mathematics, which are officially taught in English from the third grade. This exception was made in view of the difficulty of translating to Pilipino some technical and nontechnical terms used in science and mathematics, both of which are taught as separate subjects beginning with grade 3..

The Curriculum, Instructional Materials and Equipment

The curriculum for elementary and secondary schools is set by DECS and therefore is highly centralized, with the choice of textbooks controlled by DECS. The body responsible for evaluating and selecting textbooks for use in schools is the Textbook Board, composed of the two heads of the Bureaus of Elementary Education and Secondary Education and three others appointed by the President of the Philippines upon recommendation of the DECS Secretary. Three to five books are selected periodically by the Board for each subject and each grade level, and school heads, supervisors or superintendents make their choices from this preselection.

During the mid-70's the government launched a Textbook Project aimed at improving the quality of elementary and secondary education through the provision of adequate numbers of textbooks. As the student to book ratio at that time was 8:1, the project was designed to lower this significantly, to 2:1. Curriculum Development Centers (CDC's) were designated to undertake textbook development, and the University of the Philippines Institute for Science and Mathematics Education Development (ISMED) assumed responsibility for science and mathematics texts. Materials developed by the CDCs underwent trial testing and revision before finalization.

Textbooks written and published under the government's Textbook Project were distributed free to public schools, and commercial editions were available for purchase by private schools. As a result, by June 1983 the student to book ratio was reduced to 1.4:1 for elementary science and 1.6:1 for elementary mathematics (Ministry of Education, Culture and Sports and National Science and Technology Authority, 1985).

One effect of the introduction of texts developed by the CDC for science and mathematics was a gradual change in teachers' and educators' view of science teaching. A comparison of the new science textbooks with those in use before the Government Textbook Project shows that more science activities and experiments were incorporated, not as supplementary work, but as integral parts of the learning. The children were encouraged to use their senses and reasoning skills to learn science. Such a viewpoint of science learning needed an attitude change in the teacher on their concept of science teaching: from teaching passive students to encouraging curiosity and greater involvement of the students, from "teacher-telling" to "everyone finding out". Therefore the teacher must be more knowledgeable to tackle the inquisitiveness of the students, to handle unexpected teaching situations, to recognize opportunities in the surroundings for teaching particular science concepts. This necessitated a companion teacher training program to complement the textbook development efforts. Therefore programs for elementary teachers of public schools were run nationwide by science supervisors, master science teachers or staff of the CDC. Because of cost and time constraints, these courses were on two weeks duration only.

The Textbook Project was a component of a more encompassing project, implemented by the Educational Development Project Implementation Task Force (EDPITAF). Another component of the project was the distribution of science equipment to preselected schools in the less endowed areas to enable these schools to serve as centers for other neighboring schools. In the case of science and mathematics this equipment distribution effort was supplemented by the School Science Equipment Project of the National Science and Technology Authority (NSTA), MECS, United Nations Development Program (UNDP), and UNICEF. The School Science Equipment Development Project barely alleviated the plight of the elementary and secondary school science teacher, however, since (assuming one kit per school) approximately 30,000 kits would have been needed and only 8486 elementary science kits were distributed.

Testing and Accreditation

Testing is an integral part of classroom processes. Most achievement tests are teacher-made and therefore the depth of achievement measured varies from school to school, and even within school from teacher to teacher. The latter happens in schools where sectioning is done according to student ability.

Some schools also administer standardized departmental, divisional or regional tests periodically, for example at the end of a grading period, a semester, a school-year, or a span of school-years. But in the main, tests used in the classroom are not standardized.

Teacher Qualifications

All elementary school teachers must have completed a four-year college course toward the degree of Bachelor of Elementary Education. In general, however, elementary school teachers have no subject area of specialization. The science component of the elementary teaching program, comprised of 11 units of science (three courses) and 6 units of mathematics (also three courses), amounts to less than 8% of the whole program. Programs for improving elementary science teaching exist, but reach relatively few teachers. For example, four-week residential inservice training courses offered by ISMED have space for only 2-3 groups of 20 teachers annually (Ministry of Education, Culture and Sports and National Science and Technology Authority, 1985).

Student Performance

Studies of student performance reveal that science achievement is low in both elementary and secondary school. For example, a recent study of incoming first year high school students (Gonzalez, Co and Peralta, 1985) found that even the most able students had science scores below the 50% achievement level. Students from private and public city schools were among the top performers in science, with elementary school graduates from the Metro Manila region scoring highest. The study also revealed that the elementary school graduates scored poorly on questions requiring higher cognitive skills of application, analysis and problem-solving. Preliminary analyses of 17 of 24 countries participating in the Second IEA Science

Study (SISS) indicate that students from the Philippines scored least well on the science tests for both grades 5 and 8 (IEA, 1988).

Section III: Data and Analytic Method

Sample

The research reported in this paper was conducted in the Philippines during the 1983-84 school year as part of the Second IEA Science Study (SISS). The sample comprised 475 science teachers and their 16,851 fifth-grade students and was derived from a two-stage stratified random sample of classrooms. The primary sampling units were schools, which were stratified according to national region and public or private status. This yielded 13 strata for public schools (the national regions) and two strata for private schools (Metro Manila and non-Metro Manila). A random sample of elementary schools was selected, with the probability of selection proportional to size, judged by the number of classes in the school. At the second stage, a random selection of one fifth grade class per school was selected from a list of all fifth-grade classes within the school. (SISS called for assessment of 10-year-olds or fourth grade students. Since the test was to be administered in English, conforming to the Philippine medium of instruction for mathematics and science commencing in third grade, fifth grade students, who were more fluent in English, were tested instead.)

The achieved sample of 475 schools was further screened for this analysis. First, data from the two "private schools" strata (17 schools) were not included in this study. Second, only grade five classes from complete primary (grades 1-6) and complete primary and secondary (grades 1-10) schools were retained, reducing the sample by 39 schools that reported alternative grade configurations. Schools with alternative configurations were excluded because they represented "unofficial" school types. The final analytic sample contained 419 schools.

Procedure

Students were administered a science test, a mathematics test, and a background questionnaire. Teachers completed several instruments, including a background questionnaire, information about their teaching practices and characteristics of their randomly selected class. Data about the school were provided by a school administrator. Although very many measures were collected in the IEA study, only those used in this paper are described below.

Because of the size of the student sample and the focus of the research on teacher practices and classroom organization effects on average student achievement, all data have been aggregated at the classroom level. The effects of teaching practices or classroom organization on within-class variations in achievement have not been addressed in this paper. Nor does this paper address the issue of the relative impact of individual or group-level variables on achievement. Its purpose is to compare effects of alternative group-level variables (teaching processes and organization) on group-level achievement.

Measures

Science achievement. The science test used as the major dependent variable in this study was the twenty-four item SISS "core" test. The curricular content of the SISS test was decided upon by all country participants in the study, and items testing this content were constant across countries. The core test contained items covering earth science, biology, chemistry, and physics, and covered knowledge, comprehension and application (Rosier, 1987). The score was total number of correct answers, with no adjustment for guessing.

Student background. Student background variables analyzed in this paper include three conventional indicators -- age, maternal education and paternal occupation -- and three social class indicators more relevant to developing country conditions: family size, number of books in the home, language spoken at home. In addition, a proxy for prior school achievement was included, which was performance on a simple mathematics test. Although this test was administered at the same time as the science test, its contents were designed to measure mathematics skills learned by the end of grade 4; we therefore construe it as an indicator of grade 4 achievement. In all cases, data were aggregated at the classroom level.

School and classroom characteristics. Data on four school characteristics are analyzed in this paper: (a) whether or not the school was located in Manila, (b) school size, as indicated by the total number of students enrolled in the school, (c) student teacher ratio and (d) type of school (primary, grades 1-6 only, or primary plus secondary, grades 1-10). Two teacher background characteristics are analyzed: (a) teaching experience and (b) extent of post-secondary science education. Class size, defined as the number of students in the class, is also included.

Material and non-material inputs. Three inputs are examined: learning time, textbooks and laboratories. The indicator of learning time was the number of weekly hours the teacher reported teaching science to the sample class. The indicator of textbook use was the consensus of the students and teacher on frequency of use. If the teacher indicated the "the prescribed textbook" was "very important" in determining what he or she taught on a day to day basis, and at least 50% of the students in the class agreed that they "often" used a science textbook during a lesson, the class was coded as a "high textbook use" class; 32% of all classes were so categorized. The indicator of laboratory use was the teacher's report on the amount of science teaching to the sample class that took place "in a room or laboratory equipped for science teaching and/or student practical work" (Emphasis added). If the teacher indicated that 50% or more of his or her science teaching took place in a laboratory, the class was coded as a "high laboratory use" class; 42% of all classes were so categorized.

Teaching processes. Three classroom management and organizational practices are explored: grouping, testing and practical work. The indicator of small group work was the consensus of the students and teacher on frequency of use. If the teacher indicated that the class was "frequently divided into small groups of student who work together on the same assignment or different assignments, including practical/laboratory work", and at least 50% of the students in the class agreed that "often" the class "breaks into small groups of students to do experiments during science lessons" the class was coded as a "high group work" class; 10% of all classes were so categorized. The indicator of testing was the consensus of the students and teacher on frequency of occurrence. If the teacher indicated that the class was "frequently" assessed by "teacher-made objective (short answer) tests", and at least 50% of the students in the class agreed that they "often" had "tests on what [they] had learned in science", the class was coded as a "high testing" class; 29% of all classes were so categorized. The indicator of practical work was the teacher's report on the amount of "time students usually spend on practical activities on their own or in small groups; for example, doing experiments or fieldwork." If the teacher indicated that 50% or more of the student time involved practical work, the class was coded as a "high practical work" class; 57% of all classes were so categorized.

Selection of Variables

The IEA data set contains a total of 242 variables: (a) 83 variables dealing with student attitudes, test scores and background information (in addition, item-level data not analyzed in this paper contribute another 90 variables), (b) 57 teacher background variables, (c) 27 teaching process variables (not including 144 "opportunity to learn" variables not analyzed here), and (d) 75 school variables; many indicators are redundant. The specific variables included in our analytic models were identified after screening all variables included in the IEA study, eliminating at the outset variables for which no variance was observed, those having excessive numbers (more than 20% of the cases) of missing data, and those that were unrelated to the objectives of this study. For student-level data, this screening of variables was completed before aggregation at the classroom level. To reduce further the variables to a reasonable number for analysis, the following procedure was employed.

First the 419 classrooms were classified according to the mean science score of the students in the class. Five groups were formed: (a) high: mean score greater than 1.5 standard deviation above the group mean, (b) medium high: mean score between 0.5 and 1.5 standard deviations above the group mean, (c) medium: mean score between 0.5 and -0.5 standard deviations from the group mean, (d) medium low: mean score between -0.5 and -1.5 standard deviations below the group mean and (e) low: mean score less than -1.5 standard deviation below the group mean. Next, multiple Anova (for continuous variables) or Chi-square (for categorical variables) analyses were conducted with classroom science classification as the "independent" variable and the school, teacher or aggregated student variable as the "dependent" variable; variables unrelated ($p>.05$) to differences among the five classroom classifications were discarded. While the average test scores of students in high performing classrooms far exceeded those of students in the low performing classrooms[1], only 22 student background, school and teacher variables (approximately 10%) were related to average score differences and hence passed this screening. Unfortunately, a key variable--time spent on science teaching--was eliminated due to excessive missing data. One additional variable, school type (primary only or both primary and secondary), was retained without respect to screening, as it served as a prior screening criterion and could be related to absolute resources available in the school. Complete data were available for 372 classes. Descriptions of variables and summary statistics for the analytic sample of classrooms are presented in Tables 1 and 2.

Analytic Method

Two stage least squares regression[2] was used as our major analytic method, which allowed the estimation of the teaching process effects after controlling for prior achievement, peer, school and teacher background effects. At the first stage, classroom average prior achievement was predicted from classroom average peer background characteristics. At the second stage, classroom average science achievement was predicted from estimated prior achievement, school, teacher background, inputs and teaching practice variables.

Table 1: Variable names, definitions, means and standard deviations, Philippine Grade 5 science, 1983

Name	Definition
Family Background (classroom average)	
MAGE	Age of students in months
MFAMSIZE	1 = Families with < 5 children; 0 = Other
WEDUCA0	1 = Mothers with no formal schooling; 0 = Other
WEDUCA1	1 = Mothers with schooling < grade 10; 0 = Other
WEDUCA2	1 = Mothers with schooling >= grade 10; 0 = Other
FOCCR1	1 = Fathers with unskilled occupation; 0 = Other
FOCCR2	1 = Fathers with service or semi-skilled occupations; 0 = Other
FOCCR3	1 = Fathers with white collar occupations; 0 = Other
FOCCR4	1 = Fathers with professional occupations; 0 = Other
MHOMEBOO	Number of books in the home (1 = 1-10; 2 = 11-25; 3 = 26-100; 4 = 101-250; 5 = 251-500; 6 = more than 500)
MHOME1	1 = Speak local dialect at home; 0 = Other
MHOMEP	1 = Speak only or mostly Pilipino at home; 0 = Other
MHOMEE	1 = Speak only or mostly English at home; 0 = Other
School	
URSUB1	1 = School in Manila; 0 = Other
STUTOT10	Total number of students in school
RATIOST	Student teacher ratio
CLSSTP	School type (1 = secondary; 0 = primary)
Teacher and classroom	
TCHEXP1	Teaching experience in years
TPOSTS34	Postsecondary science education (1 = some; 0 = none)
NTOTIM	Number of students in class
Teacher practices	
PRACWRK2	Proportion of student time on practical work (1 = 50% or more; 0 = less than 50%)
TCHLAB2	Proportion of time teaching in lab (1 = 50% or more; 0 = less than 50%)
DTXT	Use of textbooks for teaching (1 = frequent; 0 = not frequent)
TCHTST	Use of tests (1 = frequent; 0 = not frequent)
DGRPS	Use of groups (1 = frequent; 0 = not frequent)
Student achievement	
TOT1MM	Total score on science test 1MM (range: 0 - 24)
TOT1QM	Total score on math test 1QM (range: 0 - 20)

Table 2: Variable names, means and standard deviations Philippine Grade 5 science, 1983 for total[a] data set and analytic sample

Name	N = 419b/ Mean	S.D.	N = 372 Mean	S.D.
Family Background (classroom average)				
MAGE	142.17	4.38	142.05	4.12
MFAMSIZE*	.44	.14	.44	.14
WEDUCA0*	.05	.09	.04	.07
WEDUCA1*	.47	.19	.47	.19
WEDUCA2*	.48	.20	.49	.20
FOCCR1*	.43	.26	-	-
FOCCR2*	.29	.18	-	-
FOCCR3*	.24	.16	.24	.16
FOCCR4*	.05	.06	.05	.07
MHOMEBOO	2.13	.48	2.13	.49
MHOME1*	.67	.40	-	-
MHOMEP*	.32	.40	.31	.40
MHOMEE*	.01	.04	.01	.04
School				
URSUB1*	.08	.27	.08	.27
STUTOT10	1152.91	883.66	1181.30	911.22
RATIOST	33.63	14.96	33.65	15.50
CLSSTP	.08	.28	.08	.27
Teacher and classroom				
TCHEXP1	16.91	8.44	16.94	8.52
TPOSTS34*	.15	.36	.16	.37
NTOT1M	36.15	7.27	36.13	7.20
Teacher practices				
PRACWRK2	.57	.49	.57	.49
TCHLAB2	.42	.49	.42	.49
DTXT*	.32	.47	.31	.46
DTCHTST*	.29	.46	.30	.46
DGRPS*	.10	.30	.10	.30
Student achievement				
TOT1MM	9.52	3.46	9.49	3.47
TOT1QM	10.21	2.61	10.17	2.57

*These variables are coded 0 or 1. Their mean can be interpreted as a mean % for that variable. For example, for Mfamsize, the mean of .44 can be interpreted as as meaning that 44% of students from each class come from families with 5 children or more.

a/ All non-private, complete primary (Grades 1-6) and complete secondary (Grades 21-10).

b/ Sample size for each variable ranged from 396 to 419.

The primary model we used was:

(1) $Y_{mi} = \beta_0 + \beta_1 X_i + \hat{E}_1$

(2) $Y_{si} = \beta_2 + \beta_3 Y_{mi} + \beta_4 S_i + \beta_5 T_i + \beta_6 M_i + \beta_7 P_i + \hat{E}_2$

where:

$i = 1, \ldots, k$ schools,

Y_m represents classroom average mathematics score

Y_s represents classroom average science score

X is a vector of student's background characteristics aggregated at the classroom level

S is a vector of school characteristics

T is a vector of teacher characteristics

M is a vector of material and non-material inputs

P is a vector of classroom process variables

$\hat{E}$ is an error term

and β_{1-7} are estimated regression coefficients.

Consistent with our earlier discussions, we hypothesized that if they were significantly related to achievement input and teaching process variables could interact to either complement or substitute with one another. A second model, similar to the primary model, included interaction terms.

The interaction model is:

(3) $Y_{mi} = \beta_0 + \beta_1 X_i + \hat{E}_1$

(4) $Y_{si} = \beta_2 + \beta_3 Y_{mi} + \beta_{4i} + \beta_{5i} + \beta_6 M_i + \beta_7 P_i + \beta_8 P_i M_i + \hat{E}_2$

where:

all symbols are the same as in the primary model

P_iM_i is the interaction term

and β_{1-8} are estimated regression coefficients.

Following these two analyses, we then examine teacher background determinants of particularly effective teaching practices. We focus on teacher education and experience.

Section IV: Results

Our basic hypothesis was that students in classrooms of teachers who frequently used material and non-material inputs (time, textbooks and laboratories) and who utilized effective teaching practices (spent more time on practical activities, organized students into small groups, and monitored and evaluated student performance) would outperform students in classrooms whose teachers did not use these material inputs and teaching practices, other things equal; as 46% of the classrooms lacked the time variable, this element of the first hypothesis was not investigated. Second, we hypothesized that effective teaching practices alone would contribute more to student achievement than would inputs alone, but that there would be significant interaction effects. Specifically, we hypothesized that teaching practices would interact with material inputs to either substitute or complement their effect on achievement, while teaching practices would interact with each other complementarily.

To test our hypotheses, we conducted our analyses in three stages: (a) modelling prior achievement, (b) modelling science achievement, and (c) testing for interactions.

Primary model

Modelling prior achievement. Using two stage least squares (2SLS) with list-wise deletion of missing data, we regressed average classroom mathematic achievement scores (our indicator of prior achievement) on average student background characteristics. The results are presented in Table 3, panel 1. Average student background characteristics accounted for 24% of the variance in average mathematics achievement, with five variables significantly and positively related to achievement: the average age of students in the classroom (younger classes scored higher), proportion of students having mothers with post-secondary education (classes with more educated mothers scored higher), proportion of students having fathers with white-collar occupations (classes with more white collar fathers scored higher), proportion of students using English as the home language and the proportion of students using Pilipino as the home language (classes with more non-local dialect speakers scored higher). Other social class background variables had no significant effect on average achievement. Specifically, the proportion of children coming from "smaller" families (those with fewer than 5 children), proportion of students having mothers with 1-10 years of education, proportion of students having fathers with professional occupations and number of books in the home were unrelated to mathematics achievement. The coefficients for maternal primary/secondary education and paternal professional occupation were both large and in the hypothesized positive direction, however, although the standard errors were too large for statistical significance.

Modelling science achievement. In the second stage, average classroom science achievement scores were regressed on (a) the average classroom mathematic achievement scores predicted from average peer background characteristics, (b) school characteristics, (c) teacher background and classroom characteristics, and (d) material inputs and teaching practices. The results are presented in Table 3, panel 2.

Prior achievement was the most significant determinant of science achievement, but one school characteristic and several teaching practice variables were also influential. The school's location in Manila contributed over one point to science achievement, but school size, student-teacher ratio, school type (primary only or both primary and secondary), class size, teacher experience and teacher education were all unrelated to average achievement.

Of the variables assessing the effects of inputs, one was significantly related to student achievement and one was not. High laboratory use was significantly related to student achievement, while high use of the prescribed science textbook was unrelated to achievement.

Table 3: Peer, school, teacher background and teaching practice

Equation 1 : Dependent Variable - Mathematics Achievement Score (TOT1QM)

Independent Variables

Peer	Coeff.	St. error
MAGE	-0.09*	.04
MFAMSIZ	-1.74	.93
WEDUCA1	3.29	1.85
WEDUCA2	3.74*	1.91
FOCCR3	3.65***	1.05
FOCCR4	2.05	2.31
MHOMEBOO	-0.37	.32
MHOMEE	10.13***	3.17
MHOMEP	1.36***	.33
N	372	
C	1.40	
R^2	.24	

Equation 2 : Dependent Variable - Science Achievement Score (TOT1MM)

Independent Variables	Alternative Specifications (1)	(2)	(3)	(4)	(5)
TOT1QM-hat	.81***	.83***	.82***	.80***	.83***
School					
URSUB1	1.16*	1.21	1.16*	1.23*	1.24*
CLSSTP	-.63	-.70	-.58	-.56	-.58
STUTOT10(100's)	-.01	-.01	-.01	-.00	-.01
RATIOST	-.01	-.01	-.01	-.01	-.01
Teacher and Classroom					
TCHEXP1	-0.01	-.01	-.01	-.01	-.00
TPOSTS34	0.14	.12	.15	.22	.14
NTOT1M	-.03	-.03	-.03	-.03	-.03
Teaching Practice					
PRACWRK2	-0.02	-.05	-.02	-.02	-.02
TCHLAB2	.53*	.52*	.43	.13	.37
DTCHTST	.80*	.52	.78*	.23	.64
DTXT	.08	.12	.06	.04	.07
DGRPS	1.41**	-.12	.82	1.37**	.48
Interactions					
DTCHTST*DGRPS	-	2.26*	-	-	-
TCHLAB1*DGRPS	-	-	.99	-	-
TCHLAB1*DTCHTST	-	-	-	1.23*	-
TCHLAB1*DTCHTST*DGRPS	-	-	-	-	2.15***
N	372	372	372	372	372
C	2.21	2.19	2.14	2.46	2.13
R^2	.44	.46	.44	.45	.46

*p < .05 **p < .01 ***p < .001

Of the three variables measuring teacher practices, both testing and the use of small groups were significantly related to achievement. The proportion of time spent in practical work was not. Frequent use of group work was twice as effective as frequent testing and nearly three times as effective as laboratory use in enhancing science achievement.

Secondary Model Including Interactions

In the second section of our analysis, we tested our hypotheses regarding the interactions between teacher use of material inputs and other teaching practices. Despite the lack of significant effects for textbooks and practical work, we include interactions with these variables in this stage of analysis to test for suppression effects.

Textbooks and teaching practices. We first tested the interaction of frequent textbook use with all three teaching practice variables: use of practical activities, grouping and testing. In no case was the interaction term statistically significant, and in no case did its inclusion in the equation change the significance of its component variables. As a result, we have not included the results of these tests in Table 3.

Laboratories and teaching practices. We next tested the interaction of laboratories with the three teaching practices. In this case, we found effects in the direction hypothesized for two of the practices--small groups and testing--and no effect for the third--practical activities.

1. With small groups. Teachers who teach science in laboratories can use the laboratory as another lecture room or can encourage problem solving through -- among other practices -- use of small groups. We hypothesized that the use of small groups for instruction would complement the use of laboratories, but the results of our analysis (Table 3, panel 2, column 3) fail to support this hypothesis. The effectiveness of laboratories is unaffected by frequent group work, although effectiveness of group work is slightly diminished by laboratories. Specifically, when the interaction term is not included in the model, it appears that students in classes that use laboratories frequently score about a half point higher on the test than students in classes where laboratories are not used, and that students in classes whose teachers use groups frequently score about 1.4 points higher. However, inclusion of the interaction term does not change the effect of laboratories, but it reduces the effect of groups by approximately 10%, to 1.24 points[2].

2. With testing. Laboratory work also requires feedback on the success of the work; we hypothesized that students in classes that were tested more often would benefit more from laboratory work than would students in laboratory classes lacking testing. In this case, there were no enhancements of effects (Table 3, panel 2, column 4). That is, without the interaction term, use of laboratories contributed about a half of a point to the average student score, and with the interaction taken into account, this effect was unchanged. Similarly, frequently testing alone contributed .80 of a point, and with the interaction taken into account, it contributed .75 of a point[3].

3. With practical activities. Laboratory use could also affect teaching through practical activities. However, no interaction was found here. One possible explanation for the absence of effect is that the effect of "practical activities" was already captured in questions regarding "group work" and "laboratories," and interaction effects may have been similarly captured.

Interactions between teaching practices. Third, we examined interactions between the three teaching practices. Only the interaction between testing and frequent use of groups was statistically significant (Table 3, panel 2, column 2). The effect of the interaction term was large, over 2 points, and introduction of the interaction term eliminated the statistical significance of both of its component terms in the overall equation. We estimated the separate effects of testing and group work from the coefficients provided in Table 3, Panel 2, column 2. Testing contributed .75 of a point to the average student science score, and frequent use of group work contributed .53 points[4].

Three-way interaction. Finally, we investigated the effects of the three-way interaction: do students of teachers who test, use groups frequently and teach science in a laboratory score higher on science tests than students whose teachers do not use these practices? We found that they did, with the coefficient of three-way interaction reaching statistical significance, although its effect was somewhat lower than the sum of the three practices taken individually (2.15 versus 2.74).

Determinants of teaching behavior

Having identified teaching practices and uses of material inputs that enhanced science achievement, we next sought to identify factors in teachers' backgrounds that might account for differential use of effective teaching practices. We hypothesized that if differences in teacher education and training were responsible for differences in teaching practices, then teacher training policy might emphasize such skill development. Conversely, if education and training differences were not responsible for effective teaching practices, then institutional factors -- about which we lacked information -- could play a role.

To examine the effects of teacher background of teaching practices, we conducted a series of maximum likelihood logistic regressions with frequent testing, frequent group work and use of laboratories as the dependent variables and teacher background characteristics as predictors. Variables used in this analysis are defined in Table 4; results are presented in Table 5.

Effects on testing. No teacher background characteristic had any effect on frequency of teacher testing (Table 5, column 1), and the only variable.that was related to frequent testing was average classroom achievement in mathematics, our indicator of prior achievement. Frequent testing was unrelated to the teacher's sex, age, experience, postsecondary education, inservice training, whether or not the teacher belonged to a science teachers' association, read about teaching or read science specifically. Frequent testing was also unrelated to whether or not the school was in Manila, the school size, class size, or the student teacher ratio at the school level.

Effects on group work. Group work was more frequently utilized in larger, more able classes taught by younger teachers (Table 5, column 2). This suggests that recent teacher training may have emphasized group work to offset difficulties encountered by larger classes.

Table 4: Definitions and Summary Statistics for Additional Variables Used in Table 5, Grade 5 Philippine Science Achievement

Variable Name	Definition	Mean	S.D.
INSERV	Total days of inservice on science teaching over past 12 months	3.23	1.51
SCTCHASS	Member of science teachers association (1=yes; 2=no)	1.38	0.49
READGEN	Frequency of reading academic journals or periodicals related to teaching in general (1=weekly; 2=occasionally; 3=rarely or never)	1.57	0.55
READSCI	Frequency of reading journals or periodicals on science (1=weekly; 2=occasionally; 3=rarely or never)	1.62	0.58

Table 5: Teacher background and teaching context effects on effective teaching practices in grade 5 science, Philippines 1983

Independent Variables	Dependent Variable		
	Testing	Groups	Laboratories
TSEX	.52	.06	-.20
TAGE	-.26	-.58*	.15
TCHEXP1	.01	.01	.01
TPOSTS34	-.25	.37	.38
INSERV	-.12	.11	.16*
SCTCHASS	-.31	-.03	-.38
READGEN	-.29	-.57	-.69*
READSCI	-.34	-.20	-.13
STUDTOTIO	.00	-.00	-.00
URSUB1	.29	.74	1.29*
RATIOST	-.00	-.01	-.00
NTOTIM	-.02	.06*	.01
TOTIQM	.38*	.29*	.06
C	-2.83	-4.87	-.28
N	373	377	368

* coefficient more than 2 times its standard error.

Effects on laboratory use. Laboratory use was more frequent in urban classrooms with teachers who reported receiving more inservice education related to science teaching and who read more often about teaching (Table 5, column 3).

Section V: Conclusions and Discussion

This paper has examined the effects of five science teaching practices on student achievement in 372 fifth grade classrooms in the Philippines. Two of the teaching practices involved the use of material inputs (teaching in laboratories, frequent textbook use), while three involved classroom organization and management practices (practical activities, testing, and use of groups). Using two-stage least squares regression analysis, we found that three of the teaching practices were positively and meaningfully related to science achievement, net of student background, school and teacher background effects:

(a) frequent group work, with an effect size of .41,

(b) frequent testing, with an effect size of .23, and

(c) time spent teaching in laboratories, with an effect size of .15.

These findings, summarized in Table 6, confirm much prior research in both developed and developing countries, and hold promise for improving both the quality and efficiency of education in developing countries.

Table 6: Effect size[a] of three teaching practices on science achievement in grade 5, Philippines 1983

Teaching practice	Alone	With Groups	With Testing	With Lab Use
Groups	.41	-	.15	.36
Testing	.23	.22	-	.22
Lab Use	.15	.15	.14	-

a/ Effect size is defined as the parameter estimate for the particular practice divided by the science test standard deviation for the total sample.

Improving the quality of education in developing countries requires improving the effectiveness of the schooling that is offered: increasing the learning that takes place. Both group work and testing contribute substantially to increased science achievement, with students in classes in which these practices are used significantly outperforming students in classes in which these practices are not used. Frequent laboratory use also contributes to achievement, but not as substantially.

The key to improved efficiency is the comparative effectiveness of testing and group work versus laboratories. Our research showed that the effects of group work and testing were substantially higher than those of laboratories, while the costs of the three are vastly different. One study of construction costs for general science laboratories reported costs per laboratory ranging from $31,000 in Jamaica to $92,000 in Jordan; equipment costs ranged from $11,700 in Botswana to $34,600 in Jamaica, with per student costs averaging about $65 (Mundangephuphu, 1985). By comparison, group work and testing are virtually free. The cost-effectiveness (i.e. efficiency) of group work and testing, therefore, will be much greater than the cost-effectiveness of laboratories.

Two other teaching practices -- frequent use of practical activities and frequent use of science textbooks -- were unrelated to student achievement. The failure to find an effect for textbooks is not surprising given the successful efforts of the Philippine government to infuse science classrooms with textbooks. The Philippine Textbook Project produced and distributed 97 million books covering all subject areas from first grade through high school. Textbooks were distributed nationwide at a ratio of two students per book, and by June, 1983, the student to science book ratio was 1.4. In this study, 97% of the teachers reported the use of textbooks was "Important" or "Very important" in their science teaching, and 52% of students reported using textbooks "often." Past studies of textbook effectiveness have contrasted high availability and frequent use with no availability and little use. While we did not anticipate finding no textbook effect, the widespread availability of science textbooks would have diminished their comparative effectiveness.

With respect to the negligible effect of "practical activities" on science achievement, the most plausible explanation is that the question incorporated features of both group work and laboratory work, and hence was not a clean measure of the activity itself. "Practical activities" are defined and referred to ambiguously in the survey. One definition equates practical activities with "experiments or fieldwork," while another question refers to practical activities jointly with laboratory work and embeds it in a question about small group work. A third question groups practical activities with "project work, including practical/laboratory exercises." This lack of clear definition may have resulted in confusion on the part of the respondent, and hence poor validity for the item.

This study also investigated the determinants of teacher use of effective teaching practices. In general, teachers' decisions regarding teaching practices were unrelated to their prior education or experience. Few teacher background characteristics were significantly related to use of group work, testing or laboratories. This suggests that school-level management factors may be more important in encouraging effective teaching than preservice education and training.

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End Notes

1. The sample size, mean and range of average science achievement scores for the five types of classrooms were as follows: (a) Low (N = 56 classes), M = 5.47, range = 4.0 - 6.0; (b) Medium Low (N = 117), M = 6.83, range = 6.01 - 7.74; (c) Medium (N = 164), M = 9.39, range = 7.75 - 11.15; (d) Medium High (N = 42), M = 11.86, range = 11.15 - 12.87; (e) High (N = 67), M = 15.96, range = 12.88 - 21.00.

2. The effect of laboratory use = [.43 + 0.99 (.10)] = .53, and the effect of group work = [.82 + 0.99 (.42)] = 1.24.

3. The effect of laboratory use = [.13 + 1.23 (.30)] = 50, and the effect of testing = [.23 + 1.23 (.42)] = .75.

4. The effect of testing = [.52 + 2.26 (.10)] = .75, and the effect of frequent group work = [-.12 + 2.26 (.29)] = .53.

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