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ABSTRACT

Using data from previously completed research, the authors of this report attempted to examine the relationship between class size and measures of outcomes such as student attitudes and behavior, classroom processes and learning environment, and teacher satisfaction. The authors report that statistical integration of the existing research indicated that reduction in class size is associated with higher quality schooling and more positive attitudes. The meta-analysis procedure used by the authors revealed that small class size is associated with higher quality classroom environments, better student attitudes, and greater teacher satisfaction. Findings also indicated that class size effects are related to pupil age, with effects most noticeable for children 12 years and under and least apparent for pupils 18 or over. Tables of data are included in the report. A technical explanation of integrrative analysis is appended. (Author/MK)

RELATIONSHIP OF CLASS-SIZE TO CLASSROOM PROCESSES, TEACHER SATISFACTION AND PUPIL AFFECT: A META-ANALYSIS

Mary Lee Smith
Gene V Glass

FAR WEST LABORATORY FOR EDUCATIONAL RESEARCH AND DEVELOPMENT

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The first meta-analysis, *Meta-Analysis of Research on the Relationship of Class-Size and Achievement* by Gene V Glass and Mary Lee Smith, is available through the Order Department of Far West Laboratory. The price (prepaid) is $5.50 (First Class: $7.00).

Complimentary reprints of the March 1979 Phi Delta Kappan article, *The Class Size/Achievement Issue: New Evidence and a Research Plan* by Leonard S. Cahen and Nikola N. Filby, are available by request. Write: Class Size and Instruction Project, 1855 Folsom Street, San Francisco, CA 94103.

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July 1979

PREFACE TO SECOND META-ANALYSIS

This is the second in a series of reports to be published by the Class Size and Instruction Project, of the Far West Laboratory. The first report was the Meta-Analysis of Research on the Relationship of Class-Size and Achievement, also conducted by Drs. Gene V Glass and Mary Lee Smith of the University of Colorado. This report has received national and international attention and has provided positive evidence that reduced class size and greater pupil achievement are indeed associated.

The present report provides important information about the relationship of class size and the variables of classroom or instructional processes, teacher satisfaction, and pupil affect. Again, the authors' search through the literature has uncovered many studies that have not been examined in earlier investigations of class size. Again, evidence is presented about the positive impact of reduced class size.

The two reports confront educational decision-makers with reasonable evidence that reduced class size can have positive effects upon classroom processes and pupil learning. If this evidence is convincing, educators must find ways to reduce class size for at least parts of the school day and year. The question of resource allocation becomes crucial. On one hand, the country is faced with severe problems in the financing of education; and yet, on the other hand, this country has a long history of belief in the importance of quality instruction for pupils.

In the Fall of 1979, a series of reaction papers dealing with the policy implications of the two meta-analyses will be commissioned by the Class Size and Instruction Project. I hope that the reaction papers will provide additional interpretations of the two meta-analyses and will provide insights into their policy implications for improving education.

I again wish to thank my colleague, Dr. Nikola N. Filby, for her major contributions to the Project and for her consultation on the second meta-analysis. Drs. David C. Berliner and Richard M. Jaeger provided excellent critical reviews of an early version of the manuscript. I also wish to acknowledge the continual support of Joseph Vaughan and Virginia Koehler of the National Institute of Education.

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July 20, 1979

SUMMARY

In earlier papers (Glass & Smith, 1978, 1979) we examined the relationship between class size and student achievement, through a statistical integration of existing research. Eighty studies were gathered, read, and their separate results translated into a common metric. When this metric was summarized, we demonstrated a substantial relationship between class size and achievement. As class size increases, achievement decreases.

This report extends the earlier work by examining the relationship between class size and other outcome measures, such as classroom processes and learning environment, student attitudes and behavior, and teacher satisfaction. These outcomes are valuable in their own right; to some people, even more valuable than achievement test scores. Examining multi-dimensional class-size effects also helps us understand _how_ changes in class size influence student learning.

The effects of class size on classroom processes, pupil affect and teacher satisfaction are strong and consistent. _On all measures, reduction in class size is associated with higher quality schooling and more positive attitudes_. The class-size effects were related to age of pupils, with effects most notable for children 12 years and under, and least apparent for pupils 18 or over. Reducing class size has beneficial effects both on cognitive and affective outcomes and on the teaching process itself. These relationships have not in the past been apparent because of an inability to deal with either the class sizes or the effects precisely and quantitatively. Using meta-analysis permits us to unravel the complexity and reveal the effects of class-size.

Class size affects the quality of the classroom environment. In a smaller class there are more opportunities to adapt learning programs to the needs of individuals. Many teachers avail themselves of these opportunities; others would need training to do so. Chances are good that the climate is friendlier and more conducive to learning. Students are more directly and personally involved in learning.

Class size affects pupils' attitudes, either as a function of better performance or contributing to it. In smaller classes, pupils have more interest in learning Perhaps there is less distraction. There seems to be less apathy, friction, and frustration.

Class size affects teachers. In smaller classes their morale is better; they like their pupils better, have time to plan and diversify, are more satisfied with their performance. Does this mean that class size is merely a selfish, political issue for teachers? Or is the happier teacher the one who performs better? This we cannot unravel, except to cite the other evidence--that the smaller the class is the greater is the effect on the instructional process, on pupil affect, and on achievement.

CLASS-SIZE AND NON-ACHIEVEMENT EFFECTS

INTRODUCTION

Among techniques designed to improve education, decreasing class size is the most controversial. Teachers have lauded the benefits of smaller classes. Administrators have demonstrated their high cost. Because of the costs of decreasing class size, policy-makers have demanded that it be justified on the basis of increased achievement.

Researchers have been unable to resolve the controversy by providing an unequivocal answer to the class size question. Many studies have been conducted: some showed that smaller classes were better, some showed that larger classes were better, many failed to conclude anything at all. Reviewers of the research failed to unravel the conflicting results. The conventional wisdom holds that research fails to demonstrate the efficacy or benefits of small classes.

Teachers have always been frustrated by this failure of research to confirm what from their personal experience and tacit knowledge seems so obvious. They feel that it is more difficult to work when confronted with greater numbers of students. It is harder to know each student--what Johnny's reading level is today or how to solve Jenny's current difficulty in arithmetic. The range of possible teaching strategies is restricted in large classes. With greater numbers it is harder to be effective and, hence, (in the teacher's view) the pupils learn less.

But anecdotal evidence is not honored by policy-makers. In the present political climate, one must demonstrate "scientifically" that decreasing class size has social utility--produces higher achievement test scores at a reasonable cost.

Because the research evidence appeared conflicting, the debate over increasing or decreasing class size has become more political than scientific. Constituencies pull one way or the other, each marshalling that part of the evidence that supports its own case. The decisions eventually made on class size are determined less by evidence than by which side has the greater political power.

In earlier papers (Glass & Smith, 1978, 1979) we presented the results of a statistical integration of the research on the relationship between class size and achievement. Eighty studies were gathered, read, and their separate results translated into a common metric. When this metric was summarized, we demonstrated a substantial relationship between class size and achievement. Those studies which employed rigorous controls yielded results which taken together, showed that:

> As class-size increases, achievement decreases. A pupil, who would score at about the 63rd percentile on a national test when taught individually, would score at about the 37th percentile in a class of 40 pupils. The difference in being taught in a class of 20 versus a class of 40 is an advantage of ten percentile ranks . . . . Few resources at the command of educators will reliably, produce effects of that magnitude.
>
> Glass and Smith, 1978 (p. i)

Improved academic achievement is not the only justification for decreasing class size. In a climate less influenced by the systems approach to evaluation, one might argue that achievement is not even the best criterion for judging the value of decreasing class size. After all, it is not the class size *per se* which directly affects achievement. Nor is class size the sole determinant of achievement. Achievement reflects the pupils' intellectual abilities and levels of effort as well as the classroom processes to which they are exposed. Furthermore, an assessment of school effectiveness based on achievement tests ties us to all the limitations inherent in such tests. Achievement is at best a distal effect, several steps removed from class size. More directly affected by varying class sizes, so the argument goes, are the opportunities the teacher has for doing different things. This is not to say that each teacher will avail himself of these opportunities or that those teaching strategies chosen will inevitably be more propitious. But on the average, the environment and teaching processes afforded by decreased class size may produce in turn higher achievement test results.

Differing class sizes may affect the workload, morale, and perceptions of teachers, thus producing differences in teaching performance, which again lead to variation in achievement. Furthermore, pupils' self-esteem, their satisfaction with school, and a favorable affective and social climate in the classroom are desirable effects in themselves. They may also produce or be produced by improved achievement. To the extent that decreased class size is related to a favorable affective climate, one may defend class size as an important condition, and one which is within the power of educators to manipulate.

Against these arguments for the benefits of small classes, the opposing positions must be weighed. First is the notion that teaching processes do not change as class size decreases--some teachers lecture even with a class size of ten. Nor is teacher knowledge of pupil characteristics necessary for pupil learning to take place. Second is that the positive effects of small classes on teachers merely reflect laziness or worse--a political ploy to make teaching less work or to increase the numbers of teachers, hence the power of teachers' unions. The third argument is that small classes actually harm students.

> It can be argued that reductions in class size have a very serious non-academic effect. The primary rationale offered for class size reduction is to allow more individualized attention to the pupils. It seems logical to assume that such would encourage greater dependency by the pupils, "teach" them to expect the world to take care of them, and dull their abilities to develop personal initiative. If so, our reductions in class size over the years would therefore be partly to blame for the claimed decline in the motivation and discipline of our young workers.
>
> Sagness (undated)

Thus arguments pro and con were interesting enough for us to pursue the question of whether decreasing the size of classes produces improvements on non-achievement outcomes--teaching processes, and student and teacher effects in the affective domain. As in the previous study (Glass and Smith, 1978, 1979), we addressed the question with meta-analysis--the synthesis of extant studies--and also as in the previous study, we found an affirmative answer.

METHODS OF THE STUDY

The present study should be thought of as a companion piece to the earlier meta-analysis of the effect of class-size on achievement (Glass and Smith, 1979). The same literature search produced documents for both studies. The documents were described and categorized on the same set of characteristics. The same procedures were used to quantify the outcomes generated in the documents. The statistical techniques applied to the data were modified slightly from the earlier study because of the intervening development of improved techniques. These methods are explained in this section.

LITERATURE SEARCH

Standard procedures for searching the literature were used. Secondary sources such as the Encyclopedia of Educational Research were consulted. Reviews of research such as Ryan and Greenfield (1975) yielded numerous titles. Of the documents obtained in this preliminary phase, their bibliographies led us to other titles. The ERIC system and Dissertation Abstracts were searched on the basis of keywords "size," "class size," and "tutoring." This covered the dissertation literature from 1900 to the present and the fugitive educational research literature from the mid-1960s to the present. The archival literature was searched from 1900 to the present. Abstracts and documents were scanned and those appearing to fit our requirements were bought. Many documents were sent to us by colleagues familiar with the project.*

Unlike some previous reviewers of the class size literature, we placed no restrictions on the studies selected--whether they employed rigorous empirical methods or compared classes of certain pre-determined sizes. Such restrictions often inject an unknown direction and degree of bias into the conclusions of a review. Our strategy is to categorize the features of a study, such as the sizes compared, and the degree of rigor employed in the design, and then relate these variations to differences in the size of effect produced in a study. Our requirements for selection

*The assistance of Dr. Bernard McKenna of the National Education Association is gratefully acknowledged.

of documents were liberal--the experimenter must have compared the effects of classes of two or more different sizes, the results must have been presented in some quantified or statistical form, and the study must have been conducted in some educational or quasi-educational setting. These requirements excluded articles with solely narrative presentations of experiences and opinions, theoretical pieces, and experiments in laboratory settings such as psychological studies of problem-solving in groups of various sizes. To be included, the study did not have to be focused directly on class size. Large-scale evaluation studies such as the Coleman Report were included if they had statistical relationships between class size and educational effects.

Approximately 130 documents were found to fit our selection criteria. They were subcategorized by the type of effect produced. Those dealing with achievement results were included in the first meta-analysis. Those dealing with effects other than achievement were identified for the present study. These results included affective effects on students (self-concept, interest in school, attention, attendance), effects on teachers (workload, morale, attitude toward students), and effects on the instructional processes and environment (individualization, variety of learning activities, affective climate). Some studies fell into both achievement and non-achievement categories and thus were included in both meta-analyses.

CODING CHARACTERISTICS OF THE STUDIES

Once the documents were identified and obtained, various characteristics of the research studies were coded or given quantitative descriptions. Coding the studies allowed us to address more refined research questions. For example, by coding the experimental rigor of the studies it is possible

Table 1

Class-Size (II) Coding Sheet

IDENTIFICATION:

1) Study ID#:____-____. 2) Authors:______________________. 3) Year:____

4) Source of data: __Journal __Book __Thesis __Unpublished report

5) Classification of study: __Class size __Ability grouping __Tutoring
__Psychol. experiment __Secondary analysis

6) Country of origin:____________________

INSTRUCTION:

1) Subject taught: __Reading __Math __Language __Other:______________

2) Duration of instruction: ___hrs. ___weeks

3) Supplemental vs. integral: __Instruction supplemented other large group instruction.
__Instruction constituted entire teaching of the subject.

4) Adaptation of instruction to class size:
Type of instruction in smaller class:____________________

____

Type of instruction in larger class:____________________

____

	Smaller Class	Larger Class
5) No. of pupils:	______	______
6) No. of instructional groups:	______	______
7) No. of instructors:	______	______
8) Pupil/instructor ratio:	______	______
9) Accuracy of estimate of ratio:	Lo Av Hi	Lo Av Hi

10) Instructor type: __Teachers __Adult aides of tutors __Both

11) Sex of teacher: __M __F

12) Years of teaching experience: ___years

CLASSROOM DEMOGRAPHICS:

1) Pupil ability: __IQ < 90 __90 ≤ IQ ≤ 110 __IQ > 110

2) Percent pupils female: ____%

3) Ages: 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 18+

4) Average age: ____years

STUDY CONDITIONS:

1) Study setting: __Regular classroom __Experimental setting

2) Assignment of Ss to groups: __Random __Matched __"Repeated measures"
__Uncontrolled

3) Assignment of instructors to groups: __Random __Matched __"Repeated measures"
__Uncontrolled

4) Percent attrition: Small class: ___% Large class: ___%

OUTCOME VARIABLES:

Number 1/____. Domain____. Metric____. Follow-up______(weeks).
Standardized mean difference (Small-Large)______________________________Δ
Description______________________________

Number 2/____. Domain____. Metric____. Follow-up______(weeks).
Standardized mean difference (Small-Large)______________________________Δ
Description______________________________

Number 3/____. Domain____. Metric____. Follow-up______(weeks).
Standardized mean difference (Small-Large)______________________________Δ
Description______________________________

Number 4/____. Domain____. Metric____. Follow-up______(weeks).
Standardized mean difference (Small-Large)______________________________Δ
Description______________________________

Number 5/____. Domain____. Metric____. Follow-up______(weeks).
Standardized mean difference (Small-Large)______________________________Δ
Description______________________________

Number 6/____. Domain____. Metric____. Follow-up______(weeks).
Standardized mean difference (Small-Large)______________________________Δ
Description______________________________

Domain:		Metric:
A=Student Attitude	F=Interpersonal Regard	M=Simple gain scores
B=Individualization	G=Open Education	N=Residualized gains
C=Participation	H=Other	O=Uncorrected
D=Enrichment	I	P=Categorical Percentages
E=Inappropriate Behavior	J	

to say whether larger class-size effects are produced by well-designed versus poorly-designed studies. By coding the studies for the age of the pupils used as subjects it is possible to say whether larger class-size effects are associated with younger versus older pupils. An initial review of part of the documents and discussion with experts in the field about which characteristics might interact with class-size effects resulted in a selection of characteristics of the studies to be coded. These characteristics were included in a coding sheet (see Table 1) major items of which are reported below. One coding sheet was filled out for each pair of class-sizes compared within a study. If a researcher compared classes of size 5, 10, and 15, for example, 3 coding sheets (representing 3 paired comparisons) would be filled out. The first would represent the comparison of class size 5 (small class) versus class size 10 (large class). The second would represent class size 5 (small) versus class size 15 (large). The third would represent class size 10 (small) versus class size 15 (large). Each outcome measure used by the researcher as a criterion was recorded separately as a unit of analysis of class-size effect. Suppose that in the above example two outcomes were used: pupil self-concept and classroom climate. Thus this one study would contribute 3 (paired comparisons of class sizes) X 2 (outcomes) = 6 (class-size effects). In all, the 59 studies produced 371 class-size effects, which comprised the body of data for meta-analysis.

Year of the Study. The year of publication of the study was included to check whether the class-size effect is different in different eras of research. Table 2 contains frequencies and percentages of the data base produced in different years. The earliest study was published in 1925. Half of the data base was produced by about 1969. The final year covered by this project is 1978.

Table 2

Frequencies and Cumulative Percentages

of the Data Base Produced in Years 1925-1978

Year of Study	Frequency	Percentages	Cumulative Percentages
1925-1939	26	7.3%	7.3%
1940-1944	15	4.2%	11.5%
1945-1949	1	.3%	11.8%
1950-1954	4	1.1%	12.9%
1955-1959	40	11.2%	24.1%
1960-1964	24	6.7%	30.8%
1965-1969	104	29.1%	59.9%
1970-1974	53	14.9%	74.8%
1975-1979	104	25.2%	100.0%
	371		

Source of Study. This characteristic was included to show whether unpublished materials were associated with class-size effects smaller than those produced by journal articles, books, or dissertations. As Table 3 shows, 21 percent of the comparisons of larger and smaller classes came from journals, 15 percent from books, 38 percent from dissertations and 24 percent from unpublished sources.

Type of Study. We recorded whether the focus of the study was class size *per se* rather than tutoring or a large-scale evaluation. Almost all of the studies, over 90 percent, were directly aimed at testing the effects of different class-sizes. Secondary analyses, psychological experiments on group size, and ability grouping were not included in the data base.

Country of Origin. One Australian study was included. Fifteen percent of the data base came from Canadian studies. The rest were American. The lack of variation on this characteristic prevented us from classifying the class-size effect by country of origin.

Subject Taught. We recorded the subject matter taught as the basis for the class-size experiment. The predominant category was "all subjects," representing 57 percent of the data base. These comparisons arose from experiments with all-day self-contained classrooms. Other categories contained data too sparse to answer the question of whether there is a different class size effect in teaching different subject matter. Table 4 contains the breakdown of the data base by subject taught.

Duration of Instruction. The amount of teaching was recorded in hours and weeks. The number of hours of instruction varied from a single hour to 6,000 hours with a mean of over 450 hours and a similar standard

Table 3

Frequencies and Percentages of Data Base Produced by Four Sources of Study

Source of Study	Frequencies	Percentage
Journal	75	20.2
Book	52	14.0
Thesis	139	37.5
Unpublished Report	89	24.0
Other	16	4.3
	371	

Table 4

Frequencies and Percentages of the Data Base (Deltas) Associated with Different Subjects Taught

Subject Taught	Frequencies	Percentage
Reading	2	.5
Math	1	.3
Language	3	.8
All Subjects	213	57.4
English or Writing	10	2.7
Social Studies	42	11.3
Education	22	5.9
Science	18	4.9
Other	60	16.2
	371	

deviation. Weeks of instruction varied from one to 36 with a mean of 25 and a standard deviation of 12.

Supplemental or Integral Instruction. Instruction was described as to whether it constituted all of the instruction on the subject that the pupil received ("integral") or whether it supplemented other instruction on the subject ("supplemental"). For 73 percent of the data base the instruction was integral, and for 19 percent, the categorization could not be determined.

Number of pupils, groups, and instructors. The number of pupils, instructors, and instructional groups was each recorded for the large and small class. The number of pupils was not the same as the class size since there might have been several small or large classes used in the study. The pupil/instructor ratio is the measure of class-size. The meaning of class-size in this investigation is the number of pupils under the guidance of a teaching adult for the period of time studied. One teacher with a group of 30 pupils counts as P/I = 30; two teachers in a class of 30 gives P/I = 15. One teacher and an instructional aide (not a clerical aide) in a class of 30 gives P/I = 15.

Accuracy of Estimate of Ratio. The accuracy of the determination of the P/I ratio was rated as either low, average, or high. A "high" rating meant that the exact number of pupils per teacher was known. An "average" rating meant that class-size was given as a narrow range of pupils, e.g., "25-30" or "18-21." "Low accuracy meant that class-size was reported only as a broad range, e.g., "20-30" or "less than 15." Most estimates were given an average rating.

Instructor Type. It was noted whether the instruction was given by teachers or adult aides and tutors.

Sex and Experience of Teachers. Although we intended to record these characteristics of teachers, virtually no information was available on them.

Table 5

Numbers of Pupils, Instructors, and Pupil/Instructor Ratio for Small Class/Large Class Paired Comparisons

	Small Class	Large Class
Number of Pupils in the Study		
Range	20 - ∿ 100,000	22 - ∿ 100,000
Mean	3,582	3,895
Standard Deviation	10,740	11,244
Number of Instructors in the Study		
Range	1 - ∿ 1,000	1 - ∿ 1,000
Mean	59	45
Standard Deviation	158	148
Pupil/Instructor Ratio		
Range	1 - 78	4 - 189
Mean	20	45
Standard Deviation	10	30

Pupil Ability. Average IQ of pupils was noted as either 1) below 90; 2) 90 to 110; or 3) above 110. If no information was provided by the researcher pupil ability was estimated as average. This was the usual situation, so that there was not sufficient variation to detect different class-size effects for different levels of pupil ability.

Percent Pupils Female. Although it might have been assumed that this figure would be near 50% in elementary classes, it was virtually never reported and we seldom used this variable.

Average Pupil Age. The typical age of the pupils involved in the study was noted, so that interactions between age and class-size effects could be detected. Ages ranged from 5 to 22 with a mean of 13 and standard deviation of 2.

Study Setting. The setting in which the study took place was noted. Since the studies took place almost exclusively in regular classroom settings, this variable proved irrelevant to subsequent analyses.

Assignment of Pupils and Teachers to Groups. These variables were important in describing the degrees of experimental control exercised in the study. "Random" is obvious; "matched" refers to attempts to equate small and large classes by other than random means on pretests of achievement or ability; "repeated measures" refers to using either the same pupils or teacher in both small and large classes, e.g., 10 pupils might be taught alone and then in a group of 40 and their achievement compared; "uncontrolled" should be obvious. Of the entire data-base, 16 percent came from studies which used randomization, 6 percent came from matched group studies, 17 percent came from "repeated measures" studies, and 61 percent came from uncontrolled studies.

Percent Attrition. This is also a concern for experimental validity, but it was reported too infrequently to be useful.

Metric of Measure. The metric used in the measurement of outcomes was recorded. In some instances, a degree of experimental control could be attained by expressing achievement as gains from pretest to posttest or covariance adjusting posttest means for pretest differences. However, 53 percent of the outcome measures were uncorrected for pre-existing differences. Another 40 percent used data in the form of percentages (also uncorrected). Six percent of the data were in the forms of correlations. Only three percent used corrected data.

Domain of Effect. Measures of class-size effects were coded so that any interactions between the magnitude of effect and the type of variable could be detected. The classification system was suggested by Dr. Nikola N. Filby of the Far West Lab and was modified slightly by the authors. It is presented in Table 6. Effects were grouped in various ways, and the issues involved in such groupings are discussed in the next section.

QUANTIFICATION OF EFFECTS

A simple statistic was desired that would describe the relationship between the class-size and its effects as determined by a study. No matter how many class-sizes are compared in a study, the data can be reduced to some number of paired comparisons, a smaller class against a larger class. Certain differences in the findings must be attended to if the findings are later to be integrated. The most obvious differences involve the actual numbers of pupils in what are designated "smaller" and "larger" classes and the scale properties of the measure of effect. The actual class-sizes compared must be preserved and become an essential part of our

Table 6

Primary Classification of Effects (Filby Categories)

<u>Student Attitudes</u>
Attitudes toward teachers
Attitudes toward school or class
Self-concept
Mental health
Attitude toward educational program
Motivation
Preference for class size
Attitude toward life
<u>Individualization</u>
Teacher knowledge of pupils
Amount of individual student-teacher interaction
Number of variety of activities
Amount of seatwork or students working on individual tasks
Amount of work in small groups
Teacher attention to individual students
Adaptation of teaching to individuals
Building foundation for independent work
Conferences with parents
<u>Student Participation in Learning</u>
Participation in discussions or lesson
Generation of and reponse to questions
Interest and enthusiasm for classwork
Attendance
Study habits
Student directedness
Student engagement
Difficulty in learning
Attention
On-task behavior
<u>Enrichment</u>
Creative activities
Dramatics
Divergent thinking
Use of manipulative materials
<u>Classroom Behavior</u>
Aggression
Off-task behavior
Apathy
Friction
Difficulty
Discipline
Dependence

Table 6 continued

Anxiety
Teacher control
Good behavior
Frustration
Character development

<u>Interpersonal Regard</u>
Peer group links
Student social interaction
Cohesiveness
Friendly teacher-student relationship
Sociometric choice

<u>Open Education</u>
Freedom of movement in the classroom
Student choice of activities
Informality
Social interaction

<u>Quality of Instruction</u>
Creative instruction
Use of teaching aids
Teacher organization and planning
General quality
Amount of material covered
Task structuring
Positive evaluation
Varied learning activities
Innovation

<u>Teacher Attitude</u>
Morale
Attitude toward students
Perceptions and satisfaction
Expectations for performance
Workload
Absences
Professional growth

<u>School Climate</u>
General climate
Innovations and adaptations in the school
Use of school space

descriptive measure. The measurement scale properties can be handled by standardizing all mean differences in the effect (teaching process, affective outcomes) by dividing by the within group standard deviation. The eventual measure of relationship is straightforward and unobjectionable:

$$\Delta_{S-L} = \frac{\bar{X}_S - \bar{X}_L}{\hat{\sigma}}$$

where:

$\bar{X}_S$ is the estimated mean effect of the <u>smaller</u> class which contains <u>S</u> pupils,

$\bar{X}_L$ is the estimated mean effect of the <u>larger</u> class which contains <u>L</u> pupils; and

$\hat{\sigma}$ is the estimated within-class standard deviation assumed to be homogeneous across the two classes.

The resulting effect measures or Δ's (deltas) are in a common metric which may then be summarized across studies. The Δ's are standardized mean differences for a given pair of class sizes and as such are similar to z-scores. If one assumes normality of the distribution it is possible to interpret a Δ_{S-L} of +1 to mean that the average pupil in the smaller class would score at the 84th percentile of the larger class.

When a researcher failed to report means and standard deviations for class-size effects it was necessary to solve for Δ's by using the F, t, X^2, or correlational statistics and formulas documented elsewhere (Glass, 1978; Glass and Smith, 1979). Probit transformations were used on categorical data and data reported in percentages.

INTEGRATING RESULTS OF "DIFFERENT EFFECTS"

Those who flinch at the integration of results from reading tests and math tests will find the integration of all non-achievement effects even more disturbing. These effects range from the extent of individualized instruction in the classroom to student's attitude toward life. But what these variables have in common is that each has been chosen by a class-size researcher as a hypothesized effect of varying class-size. These researchers had in mind that each of these variables related in some way to the quality of education. Despite their uniqueness, each variable can be scaled so that one end represents educational improvement or the desired state of education. At the coarsest level of aggregation, these effects answer the question, "Are small classes better learning environments than large classes?"

We moved away from this coarse level of aggregation to a more specific one, in which effects were separated into 1) affective effects on pupils, 2) effects on teachers, and 3) effects on instructional environments and processes (see Table 7). This system for scaling and categorizing effects was one of several we tried out in an attempt to find contingent (interactive) class-size effects. None of the other methods revealed such interactions, and they will not be reported here. At the most specific level were ten categories of outcome, already presented in Table 6, representing student attitudes, individualization of instruction, student participation in learning, enrichment activities, classroom behavior, interpersonal regard, "open education," general quality of instruction, teacher attitude, and school climate. Unfortunately, several of these more specific categories had insufficient data to detect interactions with the class-size effects. Those which had sufficient data produced results consistent with those of the more general grouping described above and thus are not reported here.

Table 7

Secondary Classification of Effects into Affective Effects on Pupils, Effects on Teachers and Effects on the Instructional Environments and Processes.

Student Effects
- Attitude toward teachers
- Attitudes toward school or the class
- Self-concept
- Mental health
- Attitude toward educational program
- Motivation
- Preferences for class size
- Attitude toward life
- Participation in discussions and lesson
- Generation of and response to questions
- Interest and enthusiasm for classwork
- Attendance
- Study habits
- Student engagement
- Difficulty in learning
- Attention
- On-Task behavior
- Divergent thinking
- Off-task behavior
- Apathy
- Friction
- Difficulty
- Dependence
- Discipline
- Anxiety
- Good student behavior
- Frustration
- Character development
- Peer group links
- Student social interaction
- Sociometric choice

Teacher Effects
- Teacher organization and planning
- Morale
- Attitude toward students
- Perceptions and satisfactions
- Workload
- Absences
- Professional growth

Table 7 continued

<u>Instructional Effects</u>

- Teacher knowledge of students
- Amount of individual teacher student interaction
- Number and variety of learning activities
- Amount of seatwork or student working on individual tasks
- Amount of work in small groups
- Teacher attention to individual students
- Adaptation of teaching to individuals
- Building foundation for independent work
- Conferences with parent
- Creative activities
- Dramatics
- Teacher directiveness
- Use of manipulative materials
- Amount of teacher control
- Positive teacher control
- Cohesiveness
- Friendly student teacher relationships
- Freedom of movement in classroom
- Student choice of activities
- Informality
- Social interaction
- Goal direction
- Creative instruction
- Use of teaching aids
- General quality of instruction
- Amount of material covered
- Task structuring
- Positive evaluation
- Varied learning activities
- Innovation
- General school climate
- Use of space
- Expectations for performance

STATISTICAL ANALYSIS

The over-all advantage of small classes over large classes cannot be represented simply by an average of Δ_{S-L}. Both the small class-size and the large class-size represent a wide range of values. Many techniques have been employed to state the over-all magnitude of Δ_{S-L} as a function of the size of the respective classes and the differences in the two class-sizes which were compared. After developing and evaluating these techniques, the one selected was the logarithmic model, which best represented the relationship of class-sizes and achievement effects (Barton and Glass, 1979).

The use of the logarithmic model arose from the expectation that class-size and non-achievement effects might be related in something of a non-linear fashion--reasoning that one pupil with one teacher acquires an interest in the subject of intensity $\underline{A}$, two pupils develop somewhat less intense interest, three even less, and so on. Furthermore the drop in interest from one to two pupils could be expected to be larger than the drop from two to three, which in turn is probably larger than the drop from three to four, and so on. A logarithmic curve represents one such relationship:

$$\underline{z} = \alpha - \beta \log_e C + \varepsilon, \text{ where} \qquad (1)$$

C denotes class-size.

In formula (1), α represents the effect for a "class" of one person, since $\log_e 1 = 0$, and β represents the speed of decrease in effect as a class-size increases. The general curve is graphed in Figure 1.

Formula (1) cannot be fitted to data directly because $\underline{z}$ is not measured on a common scale across studies. This problem can be circumvented by calculating Δ_{S-L} for each comparison of a smaller and a larger class

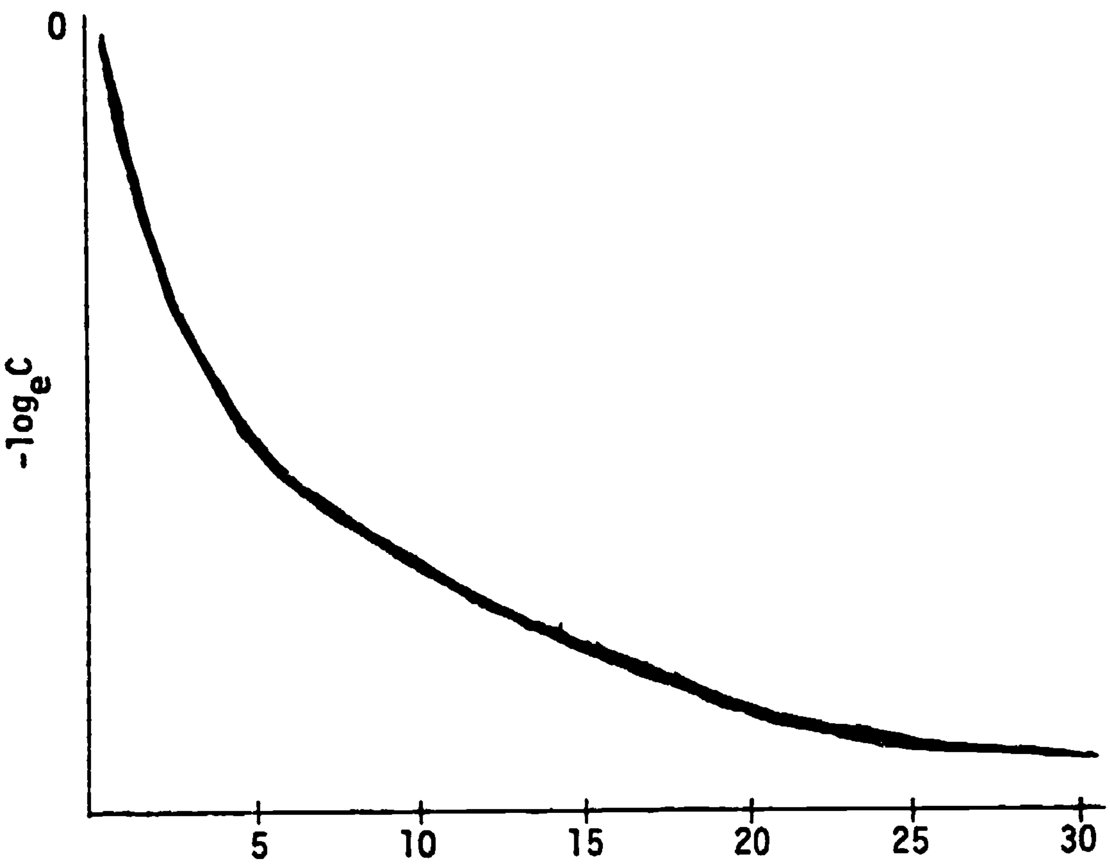

Figure 1. Graph of the log curve for the model in formula (1)

within a study. Then, from formula (1), one has

$$
\begin{aligned}
z_S - z_L = \Delta_{S-L} &= (\alpha - \beta \log_e S + \varepsilon_1) - (\alpha - \beta \log_e L + \varepsilon_2) \\
&= \beta(\log_e L - \log_e S) + \varepsilon_1 - \varepsilon_2 \\
&= \beta \log_e (L/S) + \varepsilon. \qquad (2)
\end{aligned}
$$

The model in formula (2) is particularly simple and straightforward. The values of Δ_{S-L} are merely regressed onto the logarithm of the ratio of the larger to the smaller class-size, forcing the least-squares regression line through the origin.

The solution for the least-squares estimate of β turns out to be particularly simple and straightforward.

$$\hat{\beta} = \frac{\Sigma(\Delta_{S-L})(\log_e L/S)}{\Sigma(\log_e L/S)^2} \tag{3}$$

Once β is estimated from the data Δ_{S-L} and $\log_e(L/S)$, estimates of the outcomes variable $\underline{z}$ can be obtained for the full spectrum of the class-size continuum by plotting the curve

$$\hat{z} = \hat{\beta}\log_e C \ . \tag{4}$$

The fit of the log model to the data can be examined by inspecting the scatterdiagram of Δ_{S-L} and $\log_e(L/S)$ for departures from linearity. Furthermore, if $\underline{z}$ is assumed to be normally distributed, then $\underline{\hat{z}}$ can be transformed into percentile units that can be more readily understood by many readers.

The statistical model adopted for analysis of the data in this report is believed to be an improvement over the methods used to analyze the data in our earlier work on class-size and achievement (Glass & Smith, 1978). In the former analysis, achievement was regressed onto a tri-variate linear combination of $\underline{L}$, $\underline{S}$, and $\underline{S}^2$. The equation was fit by the method of least squares estimation. This method seemed reasonable, and it was suited to the anticipated curvilinear relationship between class-size and achievement. However, it permitted no simple representation of the relationship in two dimensions where it might be easily seen and understood. Our attempt to reduce the four dimensional regression space to a plane was accomplished non-arbitrarily, but the solution by means of one or more "pivot points" seemed problematic; 1) there was more than one point that satisfied the conditions of "pivot point" and the reasons for choosing one over the others were unclear, 2) it was difficult to estimate how well determined by data the line was that resulted from constraining the four dimensional regression surface into two dimensions; and 3) the entire business was clumsy and inelegant. The logarithmic model described above had none of these shortcomings, and in addition it fit the data with a slightly smaller residual error mean square than the three parameter regression model.

FINDINGS

Despite the large range in class-sizes, there was a substantial average value for Δ_{S-L}, amounting to almost one-half standard deviation across all types of non-achievement effect. This finding indicates that "smaller is better" even before we use the loagrithmic model to define precisely what "smaller" is. The comparable finding for the achievement data--the uncorrected average Δ_{S-L}--was .011, a remarkable difference.

The subsequent findings are presented in a series of figures which depict the curves of the magnitude of effect related to class-size, first for the data as a whole and then for different parts of the data set. The metric used to display the effects consists of percentile ranks derived from standard-score equivalents. For convenience of interpretation the curves have been standardized so that a class size of 30 represents the 50th percentile of effects.

THE DATA AS A WHOLE

In Figure 2 is plotted the curve of effects calculated for class sizes 5 through 70 for the data as a whole. Table 8 contains the equivalent calculations. In column one appear the class-sizes against which the effects are calculated. Column two contains the values of $\hat{z}$, the class-size effects, calculated as follows: $\hat{z} = \hat{\beta}(\log_e C)$ where $\hat{\beta}$ is the estimated regression slope of Δ onto $\log_e(L/S)$, and C is class-size. The third column is for z' and is the adjustment of the class-size effect so that a class-size of 30 is the anchor point, at the 50th percentile of effects. The fourth column is the series of percentile equivalents for z'. Across the 371 Δ_{S-L}, the average is .49 and the standard deviation is .70. The value of $\hat{\beta}$ is .47.

These findings indicate that there is a beneficial effect on the gener l quality of the educational environment resulting from decreasing class size.

Suppose that the typical level of non-achievement benefits experienced by the average pupil in a class of 30 pupils is set equal to the 50th percentile. The results in Table 8 indicate that if this pupil were placed in a class of size 20, he would experience non-achievement benefits superior to 58 percent of the pupils who are taught in classes of size 30. In a class of 10 pupils, he will benefit more than 70 percent of the pupils in classes of 30, though he started out at the median (50th percentile) of such classes. On the other hand, increasing his class from 30 to 40

Table 8

The Calculation of Class-Size Effects for the Data as a Whole

Class Size	$\hat{z}$	z'	Percentile Rank
5	.76	.84	80th
10	1.08	.52	70th
15	1.27	.33	63rd
20	1.41	.19	58th
25	1.51	.09	54th
30	1.60	0	50th
35	1.67	-.07	47th
40	1.73	-.13	45th
50	1.83	-.23	41st
60	1.92	-.32	38th
70	2.00	-.40	37th

$\hat{\beta} = .47$

$\bar{\Delta}_{S-L} = .49$

$\hat{\sigma}_{\Delta_{S-L}} = .70$

$n_{\Delta_{S-L}} = 371$

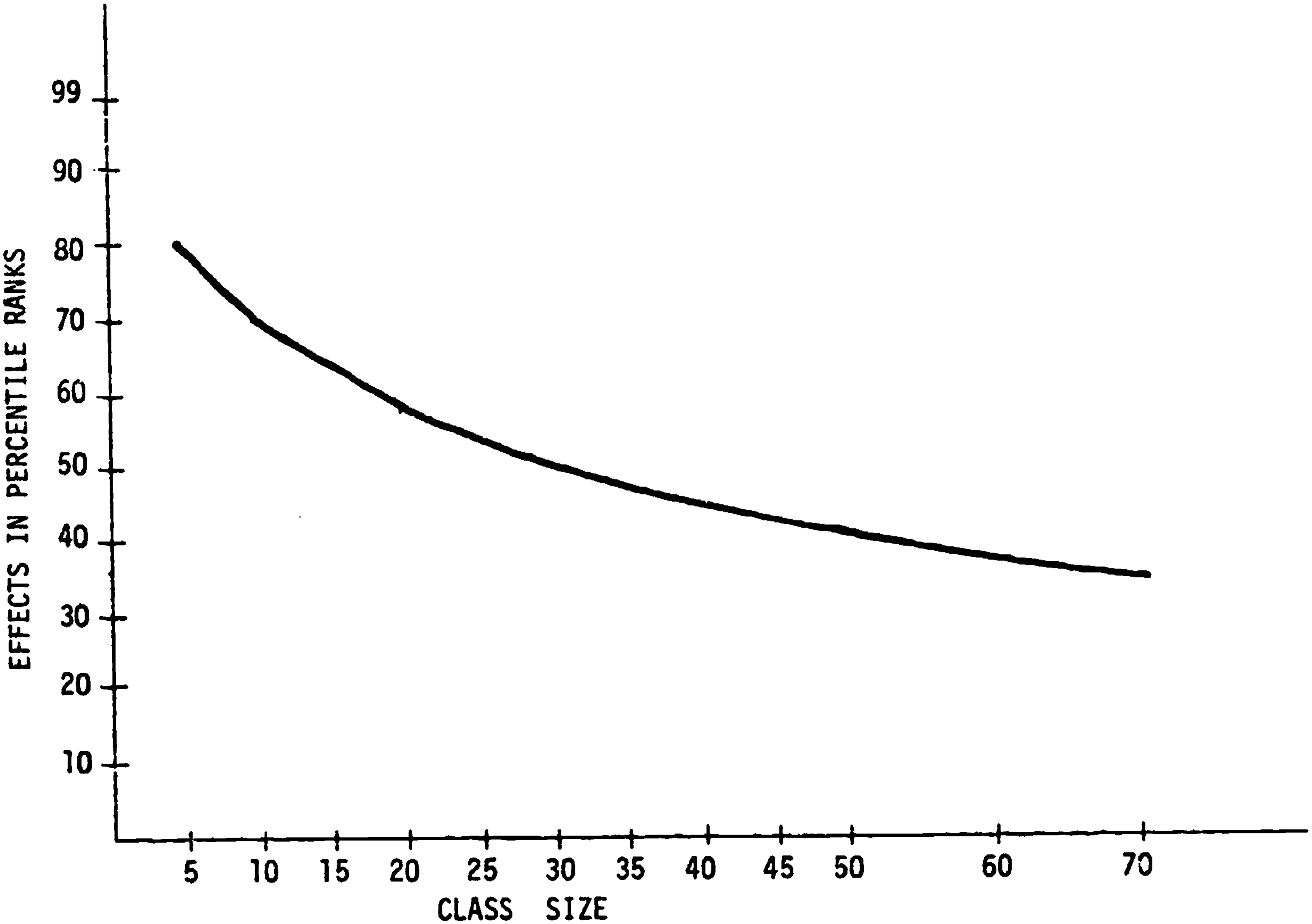

Figure 2. Graph of the relationship of class-size and effects on attitudes and instruction (the data as a whole). $n_{\Delta_{S-L}} = 371$. $\hat{\beta} = .47$.

pupils would result in a decline in non-achievement benefits; 55 percent of the pupils in classes of 30 pupils would now experience greater benefits than he. In a class of 60 pupils, this hypothetical average student would gain benefits exceeding only 38 percent of the pupils in classes of 30 pupils. Even at this coarsest level of aggregation, class-size does make a difference. Figure 3 shows the effects of class-size on achievement compared to its effects on attitudes and instruction.

The next task is to subdivide the data into more meaningful portions and to plot the class-size curve for each subset. This task answers questions about the interaction of class-size effects with different features of the studies. For example, is the class-size effect different for pupils of different ages? Is the class-size effect different for effects on teachers as opposed to effects on pupils? Unfortunately, we have many more such questions than the data can answer. We cannot say, for instance, whether the class-size effect is different for boys and girls because the distribution of gender was constant across the studies and seldom were results reported separately for boys and girls. We cannot determine whether the class-size effect is different for teachers with different levels of experience because the researchers usually failed to record teacher experience. What we do have are answers to the following interactions: the class-size effect for various outcome classifications, pupil ages, and the sources, dates, and the internal validity of the studies.

OUTCOME CLASSIFICATIONS

Probably the most meaningful classification of effects consisted of breaking them down into 1) affective effects on pupils, 2) effects on teachers, and 3) effects on the instructional environments and processes.

Figure 4, contains the curves for effects related to class-size for pupil affective effects, teacher effects, and instructional effects

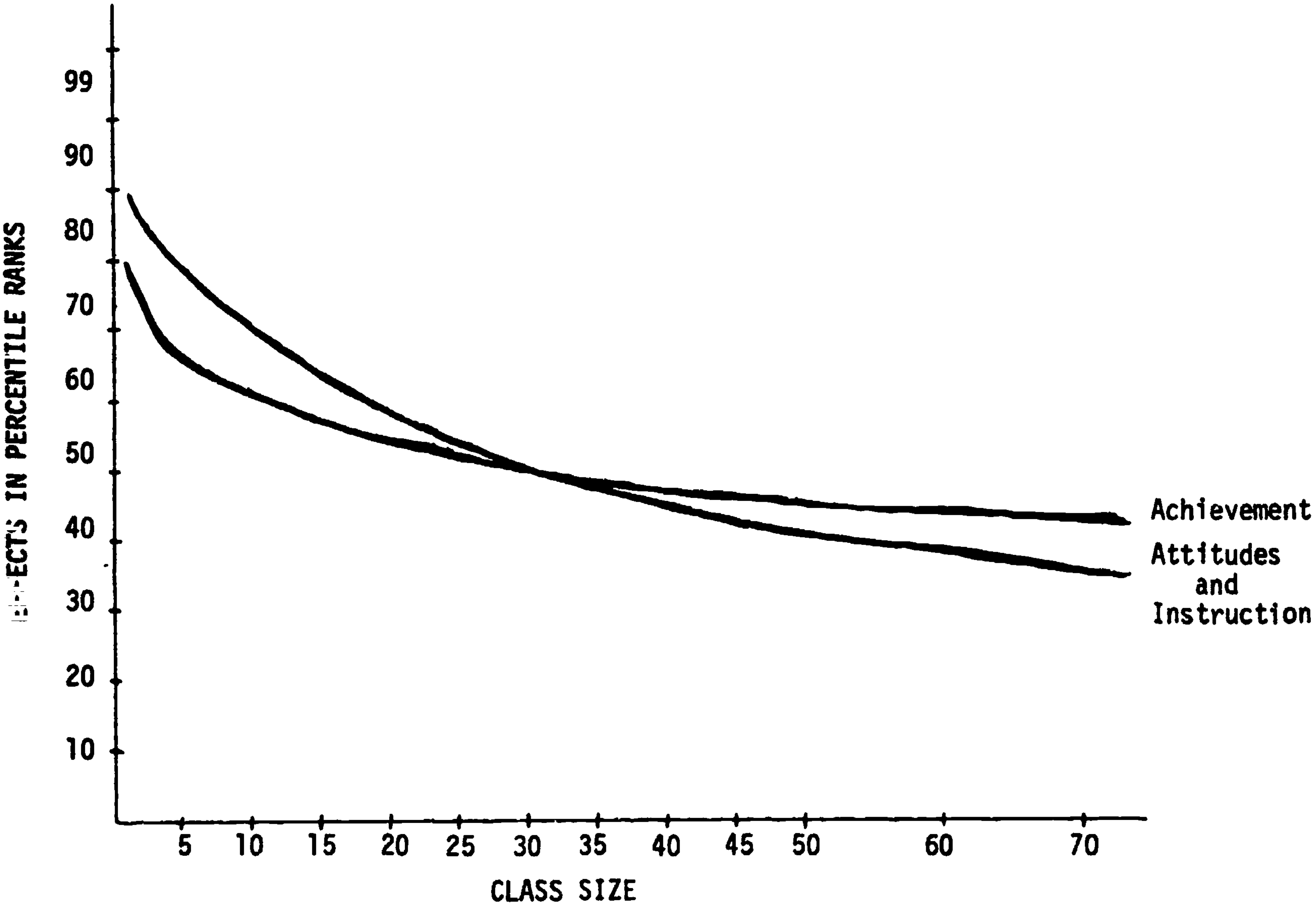

Figure 3. Graph of the relationship between class-size and achievement (after Glass & Smith, 1979 and Barton & Glass, 1979) and the relationship between class-size and attitudes and instruction (after Figure 2).

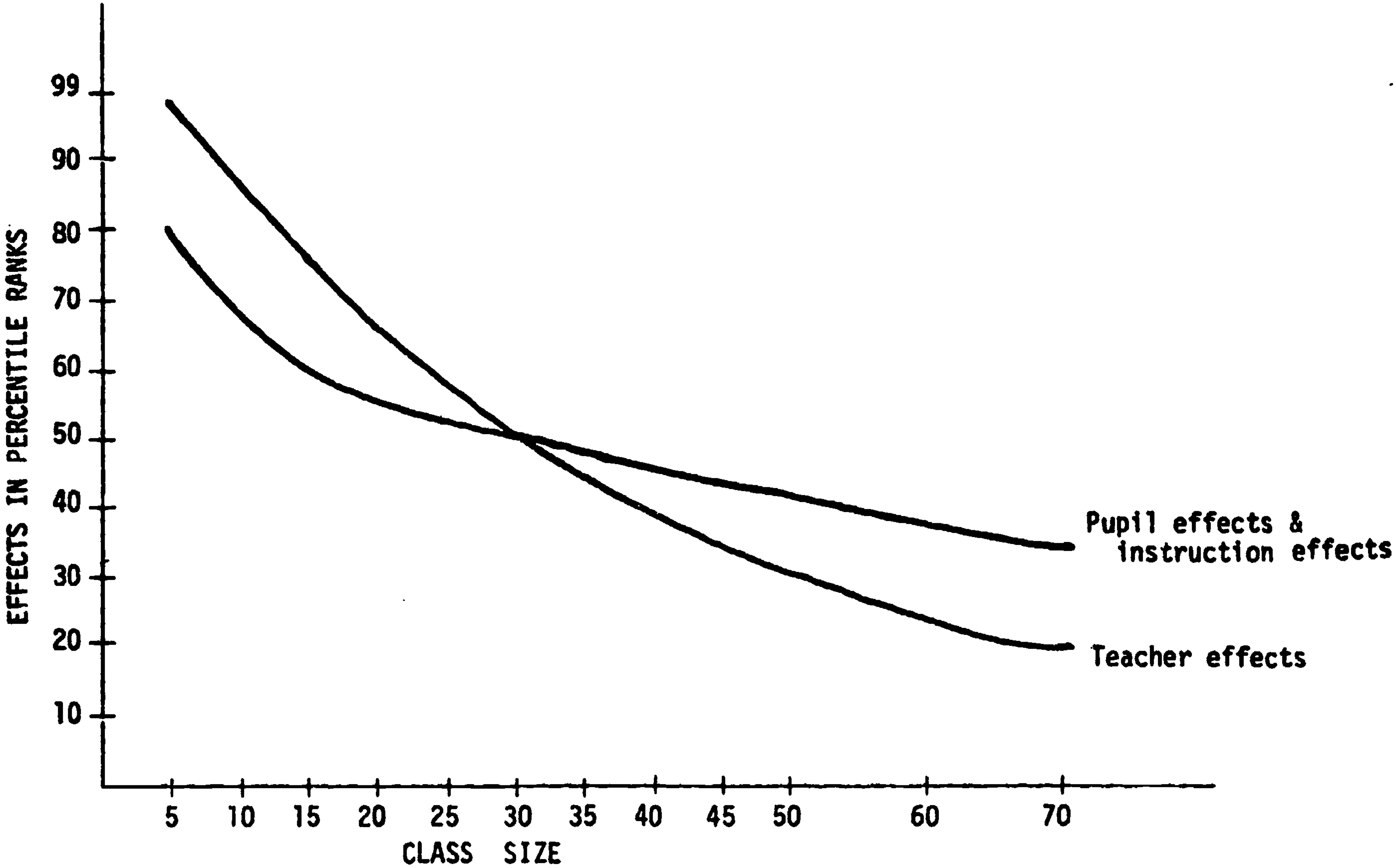

Figure 4. Graph of the relationship of class-size and affective effects on pupils ($n_{\Delta_{S-L}} = 172$, $\beta = .47$); effects on teachers ($n_{\Delta_{S-L}} = 30$, $\beta = 1.03$), and effects on instructional process ($n_{\Delta_{S-L}} = 155$, $\beta = .47$).

respectively. As can be seen from these plots, there is a difference among the three categories of effect. All three curves showed positive effects but the effects on teachers were the largest of the three.

There was a substantial effect of varying class size on teachers. The difference in a teacher's workload, attitudes about students, morale, and general satisfaction varies from the 50th percentile in a class of 30 pupils to the 76th percentile in a class of 15. The difference in teacher effects in a class of 10 versus a class of 40 is 49 percentile ranks. Thus the truism is given empirical support: teachers feel better and feel they perform better in smaller classes.

The affective effects of class-size on pupils are positive but not as dramatic as the effects on teachers. The $\hat{\beta}$ for 172 values of Δ_{S-L} is .47. Thus the difference in pupils' attitudes toward school, interest in the subject matter, classroom behavior, etc. is 14 percentile ranks between classes of size 15 and 40. A student at the 50th percentile in affective attainment in a class of 30 would be expected to rise to the 70th percentile if put into a class of 10. The size of a class does have an impact on pupils' attitudes, interests and opinions.

The effect of varying class size on instructional processes and environments is the same as the effect on pupil affect ($\hat{\beta}$ = .47 for 155 Δ_{S-L}). The opportunities for individualization, varied and adaptive learning activities, social interaction, and friendly relationships are greater in the smaller classes. Classes vary on this effect between the 70th percentile in a class of 10 pupils to the 45th percentile in a class of 40 pupils.

The effects were also categorized according to a system devised by Dr. Filby (Table 6). But five of these categories had insufficient data to estimate the logarithmic model. The results are presented in Table 9 and support the conclusions reached above, that effects on teachers are very great and effects on student attitudes, individualization, student participation in learning, and quality of instruction are positive.

PUPIL AGE

The data were categorized by age of pupils and arranged in three groups: 1) 12 years and under; 2) 13 to 17; and 3) 18 and over. The class-size effect curve was plotted for each age group, in Figure 5.

These curves show definite differences in the class-size effect for the three age groups. The effect was greatest for pupils 12 years and under ($\hat{\beta}$ = .52), somewhat less for pupils 13 to 17 ($\hat{\beta}$ = .47) and least for pupils 18 and over ($\hat{\beta}$ = .38). Thus the class-size effect does interact with pupil age.

FEATURES OF THE STUDIES

An important finding of the meta-analysis of class size and achievement was that well-designed studies produced quite different results from studies with minimal controls. The studies dealing with non-achievement effects were subdivided according to the method used by the researcher to assign subjects to experimental conditions (i.e., randomized, matched, "repeated measures" and uncontrolled).

Although all experimental methods produced positive class-size effects, there were insufficient data to estimate separately the logarithmic model for studies with "repeated measures" (n = 18). Otherwise, more pronounced results emanated from uncontrolled studies ($\hat{\beta}$ = .57) than from studies using randomization ($\hat{\beta}$ = .44) or matching ($\hat{\beta}$ = .49) as the method of assigning subjects to treatments. Figure 6 contains the curve for two contrasting experimental methods: effects of studies using randomization and effects of uncontrolled studies.

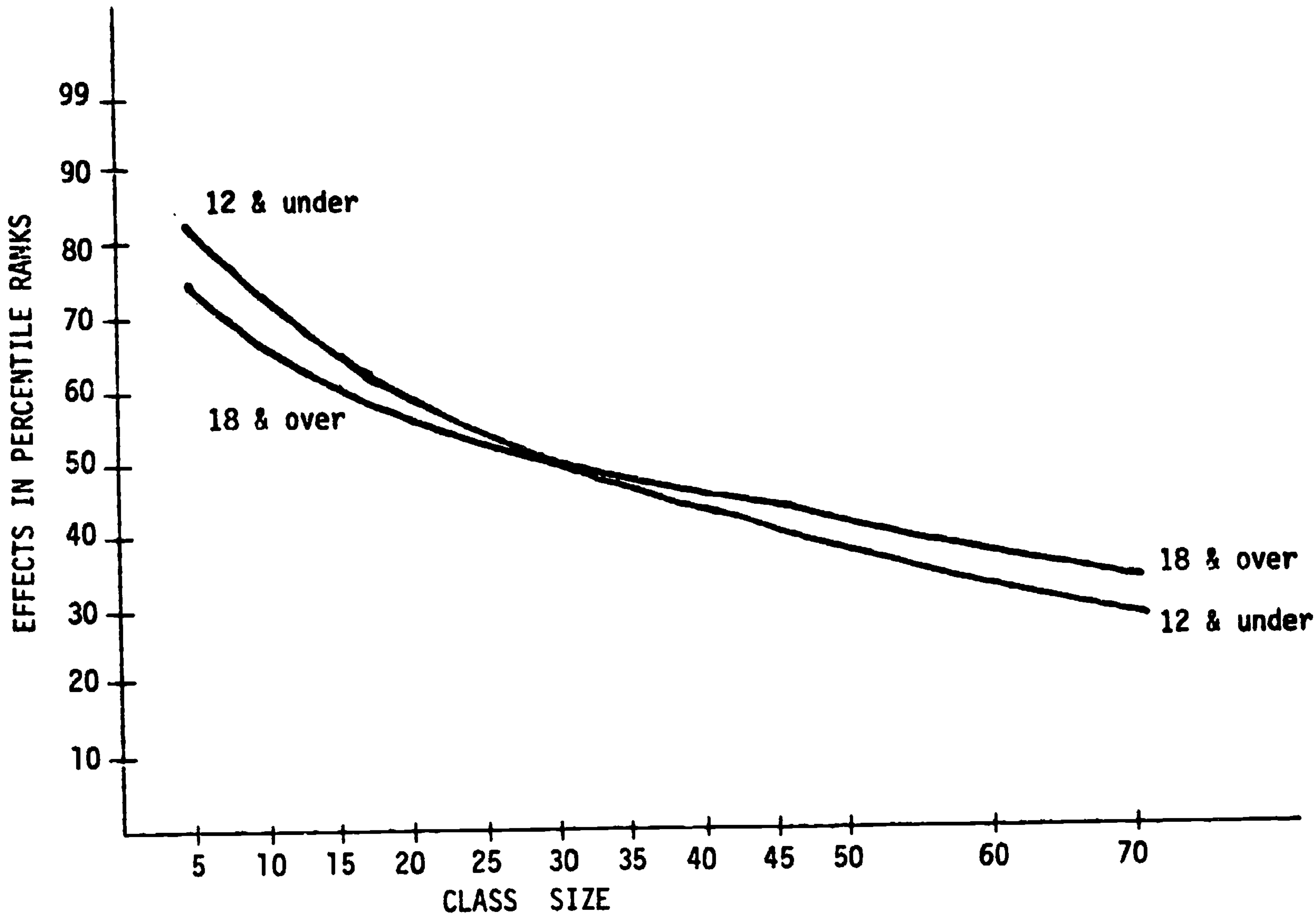

Figure 5. Graph of the relationship of class-size and effects on attitudes and instruction for pupils of different age-groups.

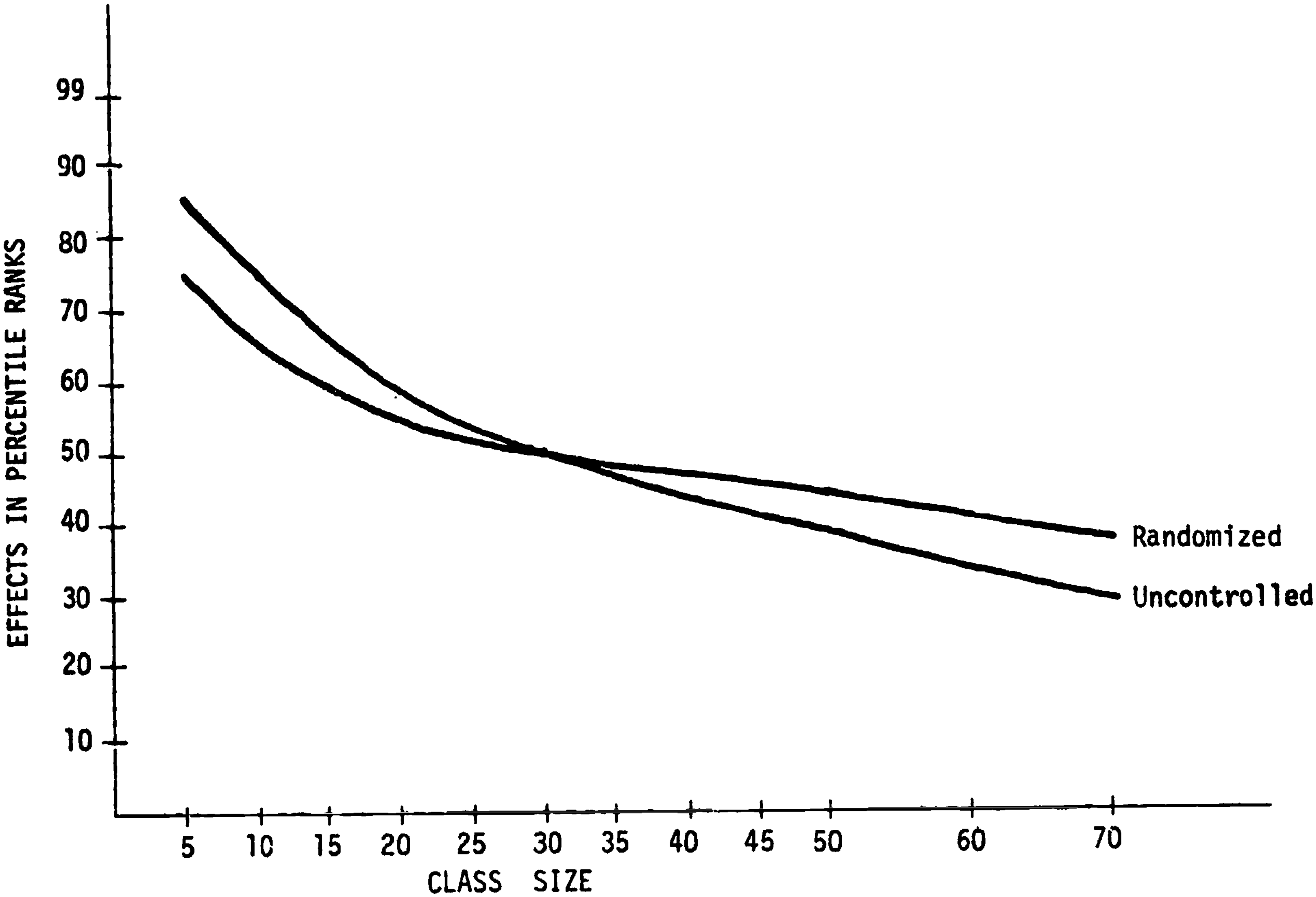

Figure 6. Graph of the relationship of class-size and effects on attitudes and instruction for studies using randomization versus uncontrolled studies (studies using matching or repeated measures produced intermediate effects and are not plotted).

Table 9

The Values of $\hat{\beta}$, Numbers of Δ_{S-L} for Effects as Categorized by Filby, with Differences in Effect Between Class-Size of 10 and 40

Category of Effect	$n_{\Delta_{S-L}}$	$\hat{\beta}$	Differences in Effects Between Class-Size 10 and 40 (Percentile Ranks)
Student Attitude	58	.43	29
Individualization	59	.36	19
Student Participation	109	.42	23
Enrichment	3	.70	*
Pupil Behavior	17	.79	*
Interpersonal Regard	19	.59	*
Open Education	4	2.28	*
Quality of Instruction	45	.31	17
Teacher Attitude	40	2.29	74
School Climate	7	2.11	*

*Insufficient data to estimate effects.

One explanation is that the poorly-designed studies are not credible and that the over-all class-size effect is inflated because 60 percent of the effects come from uncontrolled studies. The more optimistic view is that the effect of class size on the quality of education is a robust effect, detectable even with less sophisticated and powerful research methods.

To find out whether the class-size effect was conditional on the source of the study, the model was determined separately for journal articles, books, theses, and unpublished papers and plotted in Figure 7. A difference in the class-size effect was found in decreasing order from unpublished papers ($\hat{\beta}$ = 1.13) to books ($\hat{\beta}$ = .82) to journal articles ($\hat{\beta}$ = .54) to theses ($\hat{\beta}$ = .35). We made no attempt to explain this ranking except to highlight the need for reviewers to look at all sources of study lest a biased estimate of effects be made.

The median year of publication was 1969 and the studies were so divided to see if the class-size effect was greater in the more recent research (see Figure 8). This was not the case. The class-size effect was greater in studies published before 1969 ($\hat{\beta}$ = .59) than later ($\hat{\beta}$ = .42). The direction of results was the same, the magnitude of relationship differed. This is a less suspicious finding than if the direction differed.

The scatter-diagrams of the relationship between $\text{Log}_e(L/S)$ and Δ_{S-L} are presented in Figures 9, 10, and 11 for Student, Teacher, and Instructional Effects, respectively. The data revealed basically linear relationships for Student and Teacher Effects. An initial scatter-plot of the 155 Instructional Effects revealed a confusing shape with possible curvilinearity. To obtain a better picture of the shape of the relationship, multiple measures for a particular comparison of S and L within a study were averaged; 73 data points resulted. It then became apparant that seven outlying points were distorting the basic shape revealed by the scatter-plot; five of these points came from a single study. The removal of these seven points produced the scatter-diagram in Figure 11, which reveals a generally linear shape. The linearity in the scatterplots is support for the adequacy of the logarithmic model to represent these data.

DISCUSSION

Reducing class size has beneficial effects both on cognitive and affective outcomes and on the teaching process itself. These relationships have not in the past been apparent because of an inability to deal with either the class sizes or the effects precisely and quantitatively. Using

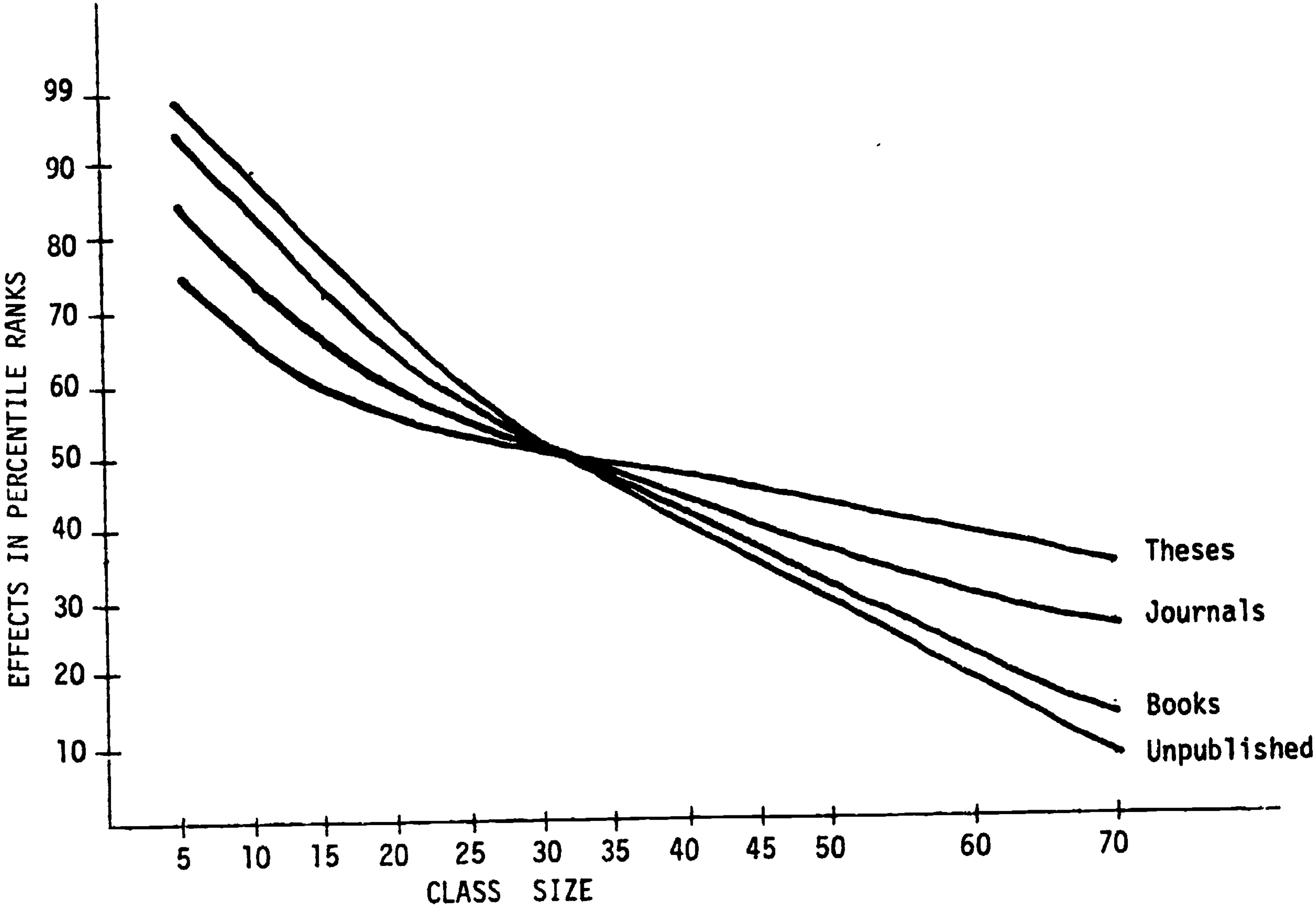

Figure 7. Graph of the relationship of class-size and effects on attitudes and instruction for four sources of publication.

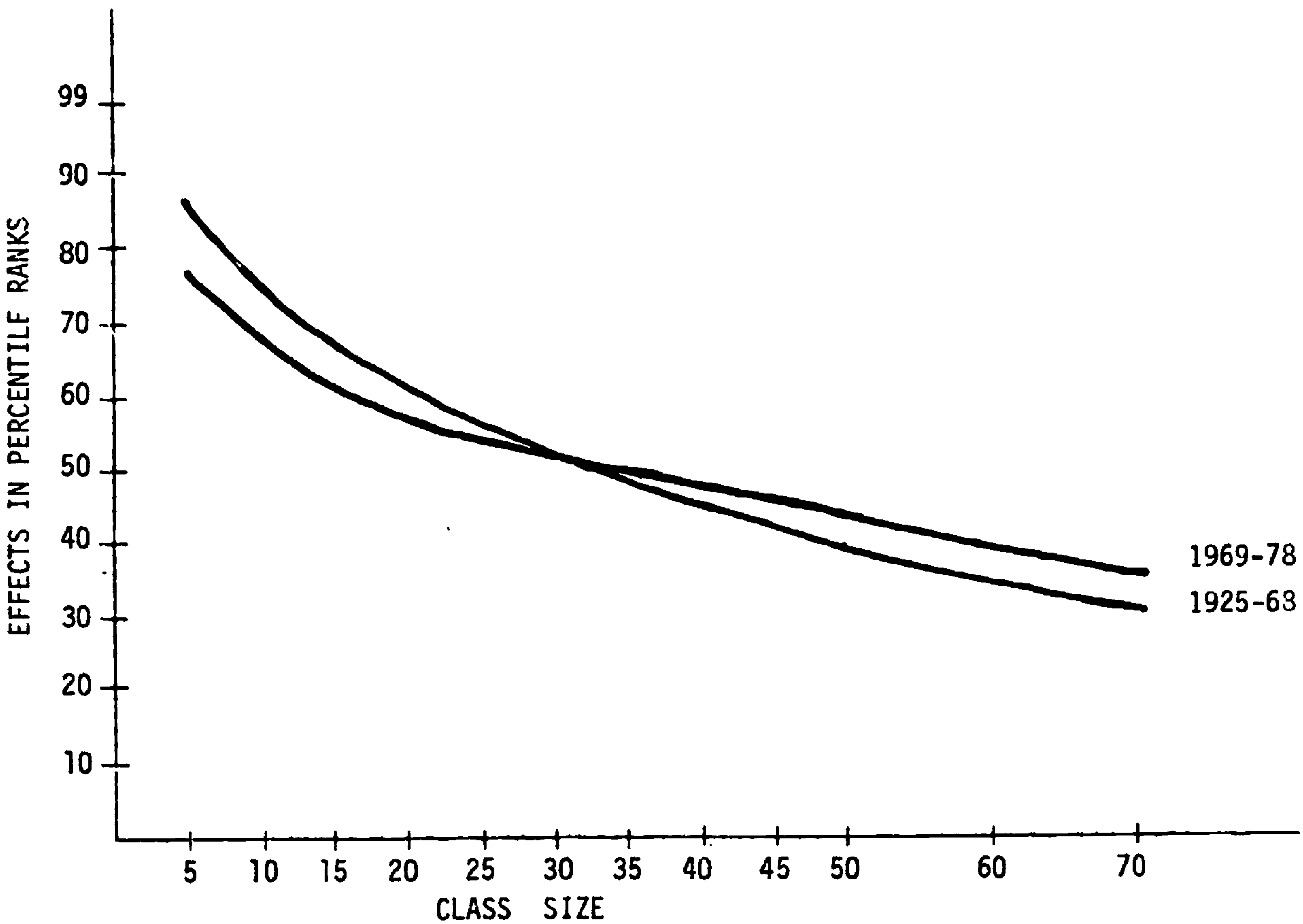

Figure 8. Graph of the relationship of class-size and effects on attitudes and instruction for studies done 1925-1968 and 1969-1978.

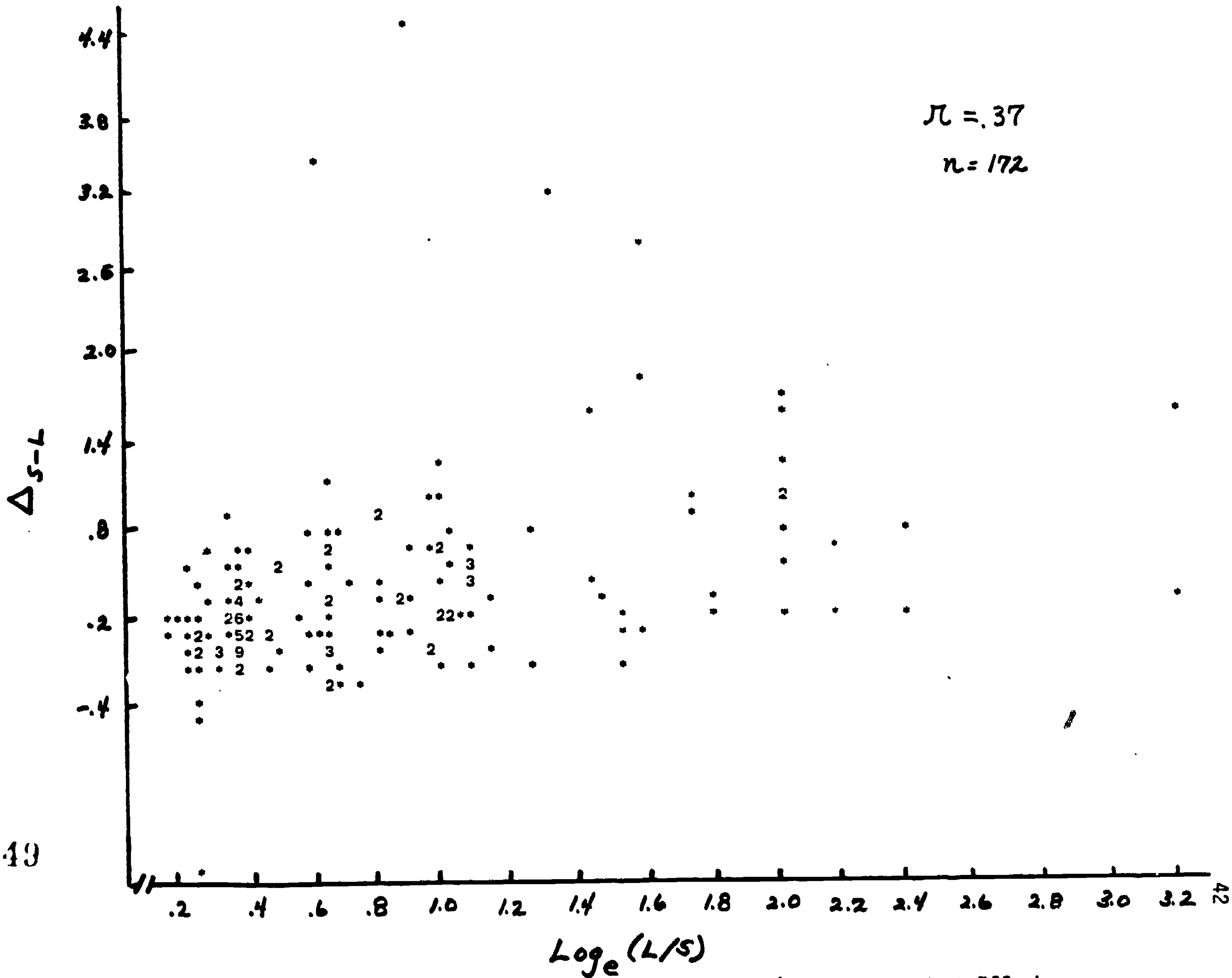

Figure 9. Scatter-diagram of the relationship of $Log_e(L/S)$ to Δ_{S-L} for Student Effects

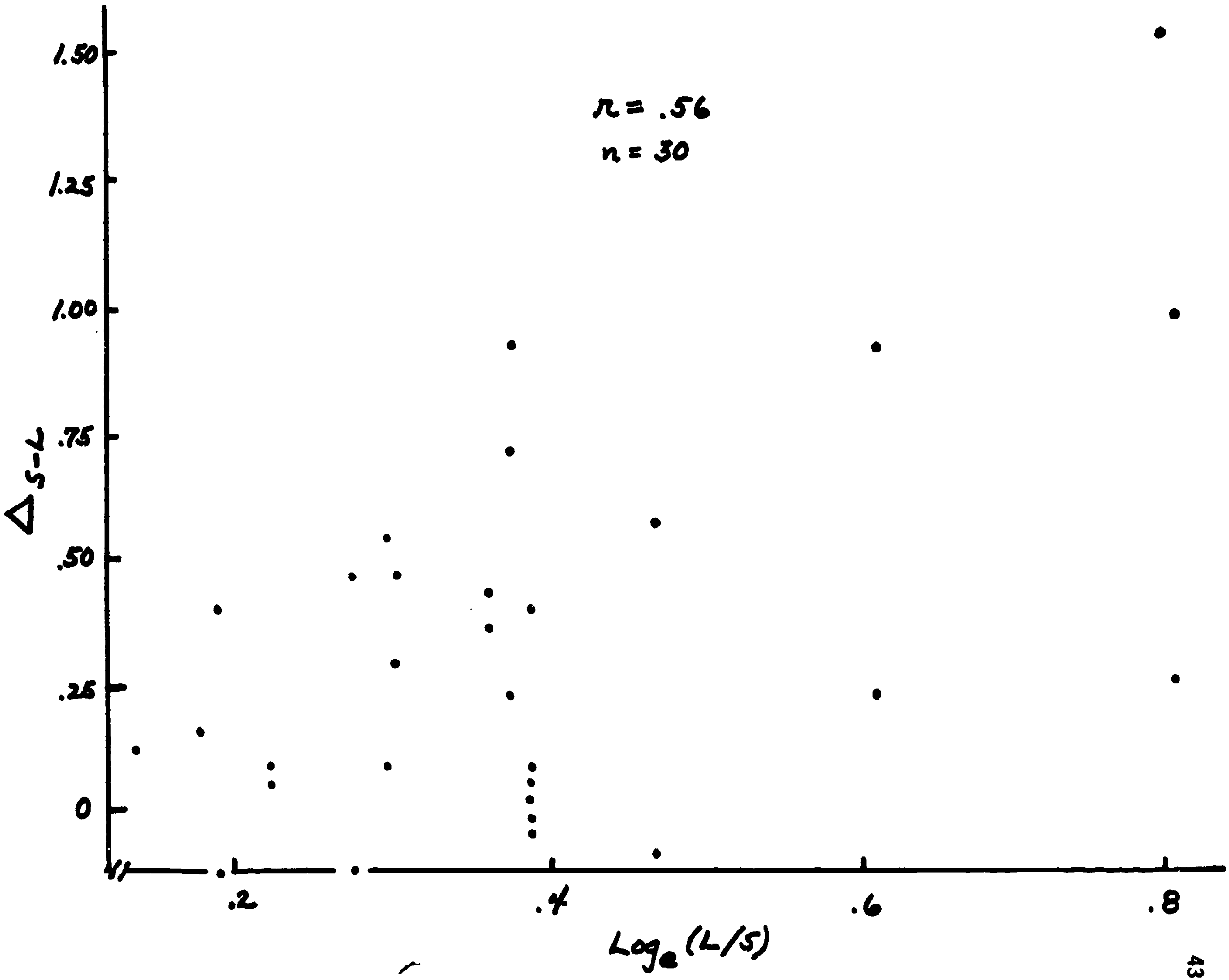

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Figure 10. Scatter-diagram of the relationship of $Log_e(L/S)$ to Δ_{S-L} for Teacher Effects

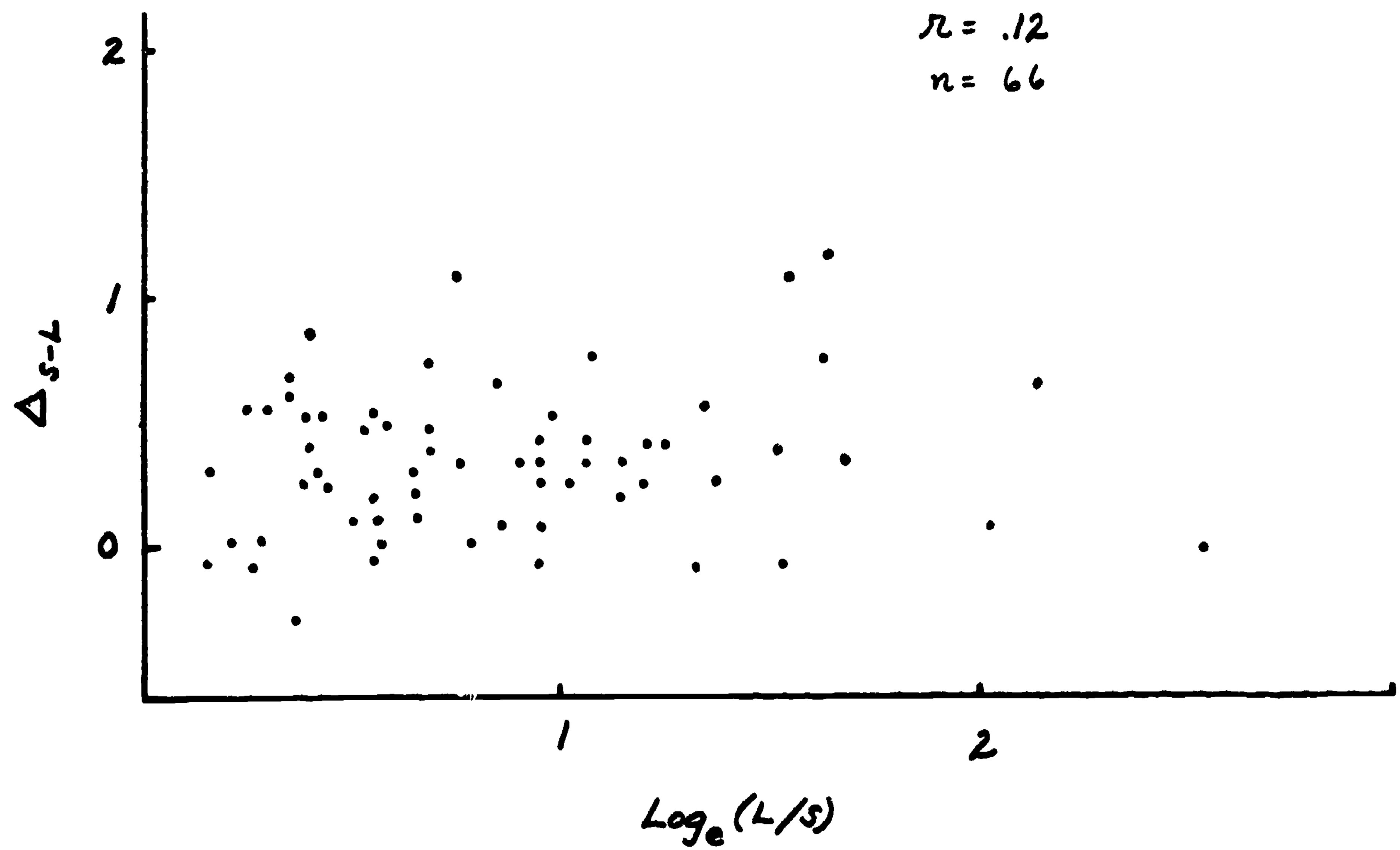

Figure 11. Scatter-diagram of the relationship of $Log_e(L/S)$ to Δ_{S-L} for Instructional Effects

meta-analysis permits us to unravel the complexity and reveal the small but consistent effects of class-size.

In the achievement study it was shown that more than 30 percentile ranks exist between the achievement of a pupil taught individually and a pupil taught in a class of 40. In the study reported here the difference in the quality of the educational environment between a class size of 1 and a class size of 40 is 46 percentile ranks.

The class-size effect is positive, no matter how that effect was measured. The most dramatic effects were those relating to teachers, smaller but still substantial were affective effects on pupils and effects on the instructional process. The class-size effects were related to age of pupils, with effects most notable for children 12 years and under, and least apparent for pupils 18 or over.

Some features of the study interacted with the class-size effect. Well-controlled studies produced slightly smaller class-size effects than uncontrolled studies. Some readers will want to adjust downward their mental estimate of class-size effects. But the difference in effects produced between the two sets of studies amounts to only about 10 percentile ranks even at the extreme points (less than 5 or more than 50 pupils) of the class-size scale. Studies completed before 1968 produced slightly higher class-size effects. Studies gleaned from dissertations produced smaller class-size effects than studies from other sources.

Even with these few qualifications made, one may still have confidence that class size is related to pupil and teacher affect and instructional processes.

Class size affects the quality of the classroom environment. In a smaller class there are more opportunities to adapt learning programs to the needs of individuals. Many teachers avail themselves of these opportunities; others would need training to do so. Chances are good that the climate is friendlier and more conducive to learning. Students are more directly and personally involved in learning.

Class size affects pupils' attitudes, either as a function of better performance or contributing to it. In smaller classes, pupils have more interest in learning. Perhaps there is less distraction. There seems to be less apathy, friction, frustration.

Class size affects teachers. In smaller classes their morale is better; they like their pupils better, have time to plan, diversify; are more satisfied with their performance. Does this mean that class size is merely a selfish, political issue for teachers? Or is the happier teacher the one who performs better? This we cannot unravel, except to cite the other evidence--that the smaller the class is the greater is the effect on the instructional process, on pupil affect, and on achievement.

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Integrating Studies That Have Quantitative Independent Variables*

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Some types of research study have both dependent, Y, and independent, X, variables that can be quantitatively measured, e.g., amount of reinforcement (independent) and time-to-criterion (dependent), engaged study time (independent) and learning (dependent), or class-size (independent) and achievement (dependent). One desires a technique for integrating many separate studies into an aggregate description of the relationship between the two quantitative variables. The search for such a technique encounters two complications: 1) the values of the independent variables observed in a study may be quite different, and 2) the scales of measurement (mean and variance) of the dependent variables may be quite different as well.

The second complication can be resolved readily. The dependent variable difference in the study between independent variable values X_1 and X_2 can be standardized via

$$\Delta_{X_1-X_2} = \frac{\bar{X}_1-\bar{X}_2}{\hat{\sigma}} \text{, where } \hat{\sigma} \text{ is an} \tag{1}$$

assumed homogeneous within-group standard deviation.

However, the first complication is more problematic. That no two studies need include the same values of X_1 and X_2 makes the representation of the X and Y relationship very complex. This is so in part because Δ is a differential, not a measure on a scale with a non-arbitrary zero point.

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One solution to the problem of depicting the $\underline{X}$ and $\underline{Y}$ relationship is to regress Δ onto $\underline{X}_1$ and $\underline{X}_2$ in a three-dimensional space. (An extension of this approach was used by Glass and Smith (1979) in their study on class-size and achievement.) The major drawback of this solution is that the relationship among two variables has been complicated by expression as a relationship among three variables; thus it is inaccessible to many who can comprehend a simple graph but not a complex one. Moreover, in reducing the three-dimensionsal relationship to two dimensions by imposing restrictions (Glass and Smith, 1979), the mathematics grows complicated and attendant problems of statistical inference are obscured.

A simpler solution is desirable, and one or two have been found.

A Logarithmic Model

Consider an illustration from research on class-size and achievement. Fourteen experiments were found in which pupils were randomly assigned to classes of different sizes. These fourteen studies yielded over 100 separate comparisons of achievement in smaller and larger classes. The multiplicity of findings is due partly to the fact that in one study there may exist several pairs of class sizes and partly to the fact that a single pair of class sizes may have been measured on more than one achievement test. The latter multiplicity was averaged out and the former retained in the summary of 30 data points in Table 1.

One might expect class-size and achievement to be related in something of an exponential or geometric fashion--reasoning that one pupil with one teacher learns some amount, two pupils learn less, three pupils learn still less, and so on. Furthermore, the drop in learning from one to two pupils could be expected to be larger than the drop from two to three, which in turn

Table 1

Data on the Relationship of Class-size and Achievement from Studies Using Random Assignment of Pupils. (Outcomes scaled via formula (1), with $\hat{\sigma}=(s_L+s_S)/2$.)

Study Number	Size of Larger Class	Size of Smaller Class	Δ_{S-L}
1.	1.	25.	.32
2.	1.	3.	.22
2.	1.	25.	1.52
2.	3.	25.	1.22
3.	17.	35.	-.29
4.	28.	112.	-.03
5.	1.	2.	.36
5.	1.	5.	.52
5.	1.	23.	.83
5.	2.	5.	.22
5.	2.	23.	.57
5.	5.	23.	.31
6.	15.	30.	.17
7.	16.	23.	.05
7.	16.	30.	.04
7.	16.	37.	.08
7.	23.	30.	.04
7.	23.	37.	.04
7.	30.	37.	0
8.	20.	28.	.15
9.	26.	50.	.29
10.	1.	32.	.65
11.	15.	37.	.40
11.	15.	60.	1.25
11.	37.	60.	.65
12.	1.	8.	.30
13.	15.	45.	.07
14.	1.	14.	.72
14.	1.	30.	.78
14.	14.	30.	.17

$$\Delta_{S-L} = \frac{\overline{X}_S - \overline{X}_L}{(s_S + s_L)/2}$$

n = 14 studies

N = 30 comparisons

is probably larger than the drop from three to four, and so on. A logarithmic curve represents one such relationship:

$$y = \alpha - \beta \log_e C + \varepsilon \text{, where} \qquad (2)$$

C denotes class-size.

In formula (2), α represents the achievement for a "class" of one person, since $\log_e 1 = 0$, and β represents the speed of decrease in achievement as a class-size increases. The general curve is graphed in Figure 1.

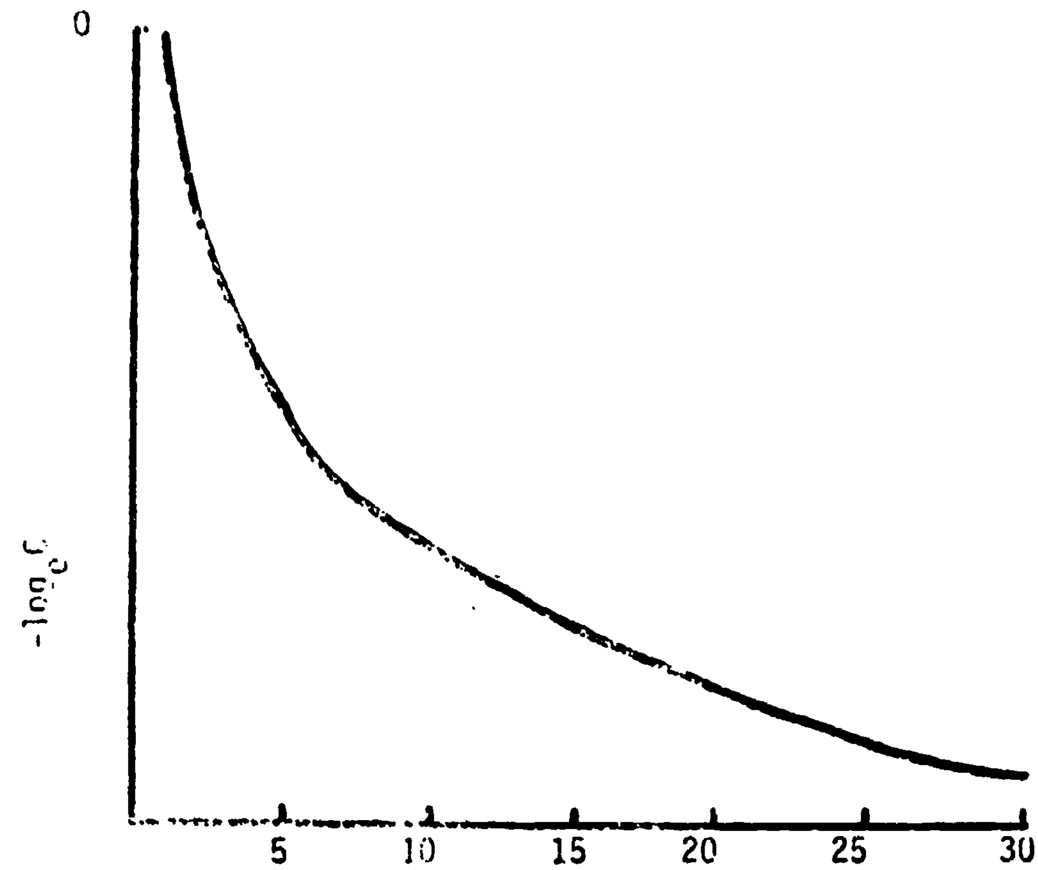


Figure 1. Graph of the log curve for the model in formula (2).

Formula (2) can not be fitted to data directly because Y is not measured on a common scale across studies. This problem can be circumvented by calculating Δ_{S-L} for each comparison of a smaller and a larger class within a study. Then, from formulas (1) and (2) one has

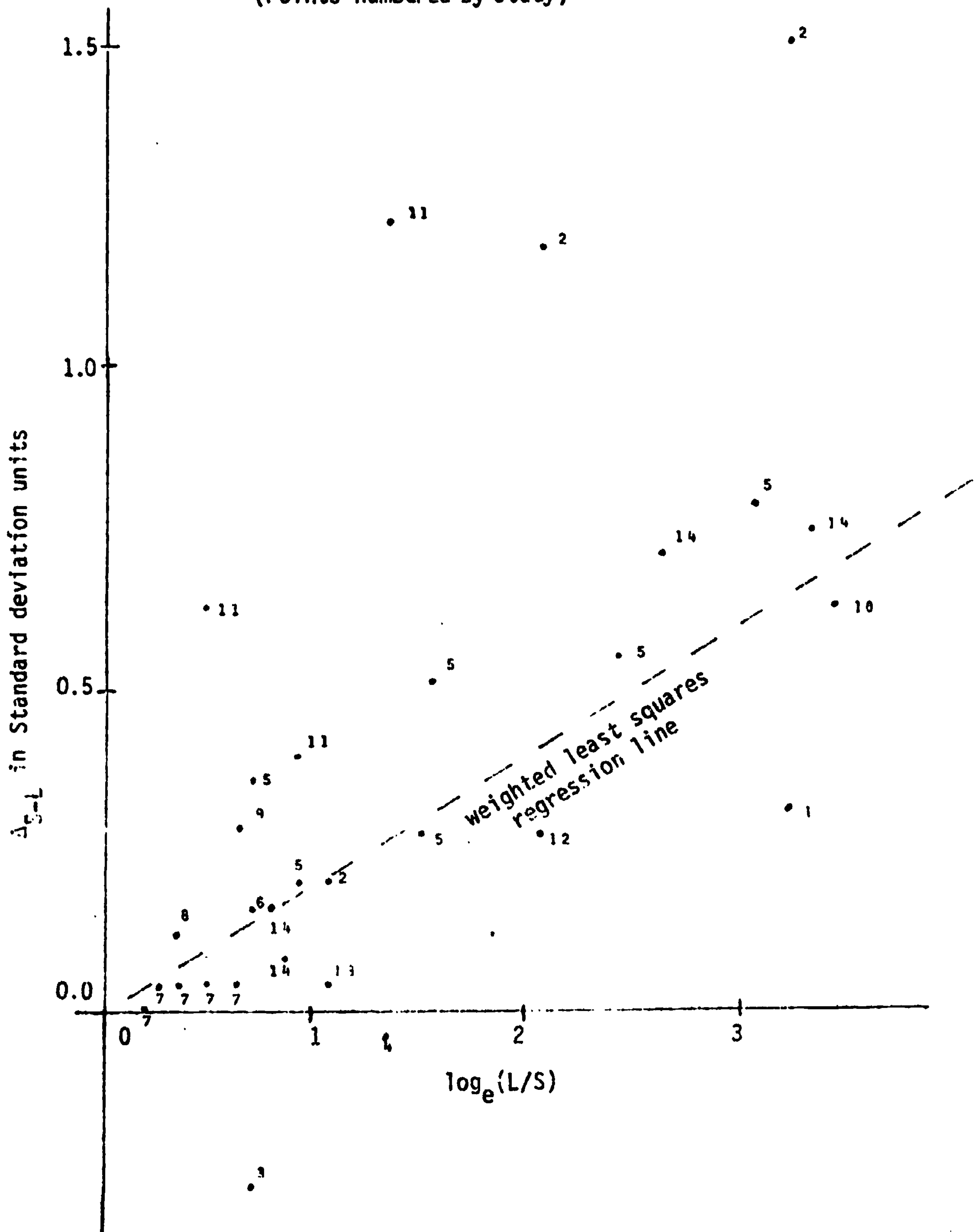
$$\begin{aligned}\Delta_{S-L} &= (\alpha - \beta \log_e S + \varepsilon_1) - (\alpha - \beta \log_e L + \varepsilon_2) \\ &= \beta(\log_e L - \log_e S) + \varepsilon_1 - \varepsilon_2 \\ &= \beta \log_e (L/S) + \varepsilon. \qquad (3)\end{aligned}$$

The model in formula (3) is particularly simple and straightforward. The values of Δ_{S-L} are merely regressed onto the logarithm of the ratio of the larger to the smaller class-size, forcing the least-squares regression line through the origin.

Figure 3

Scatter Diagram of Δ_{S-L}

Graphed Against $\log_e$ (L/S).
(Points numbered by study)



$$\hat{\beta} = \frac{\Sigma(\Delta_{S-L})(\log_e L/S)}{\Sigma(\log_e L/S)^2}.$$

A scatter diagram of the data in Table 1 appears as Figure 2, in which Δ_{S-L} is graphed against $\log_e(L/S)$. The estimate of β for these data equals 0.27. The value of r is .64, and r^2 = .42. The resulting curve relating class-size C to achievement in standard-score units appears as Figure 3.

One can either weight each Δ_{S-L} in Table 1 equally in deriving an estimate of β, or it can be reasoned that each of the fourteen studies should receive equal weight so that each Δ_{S-L} is multiplied by $2/(k^2-k)$ when it is derived from a study involving k different class-sizes. The estimate of β from the regression involving weighted Δ's is equal to 0.21, which agrees closely with the earlier result.

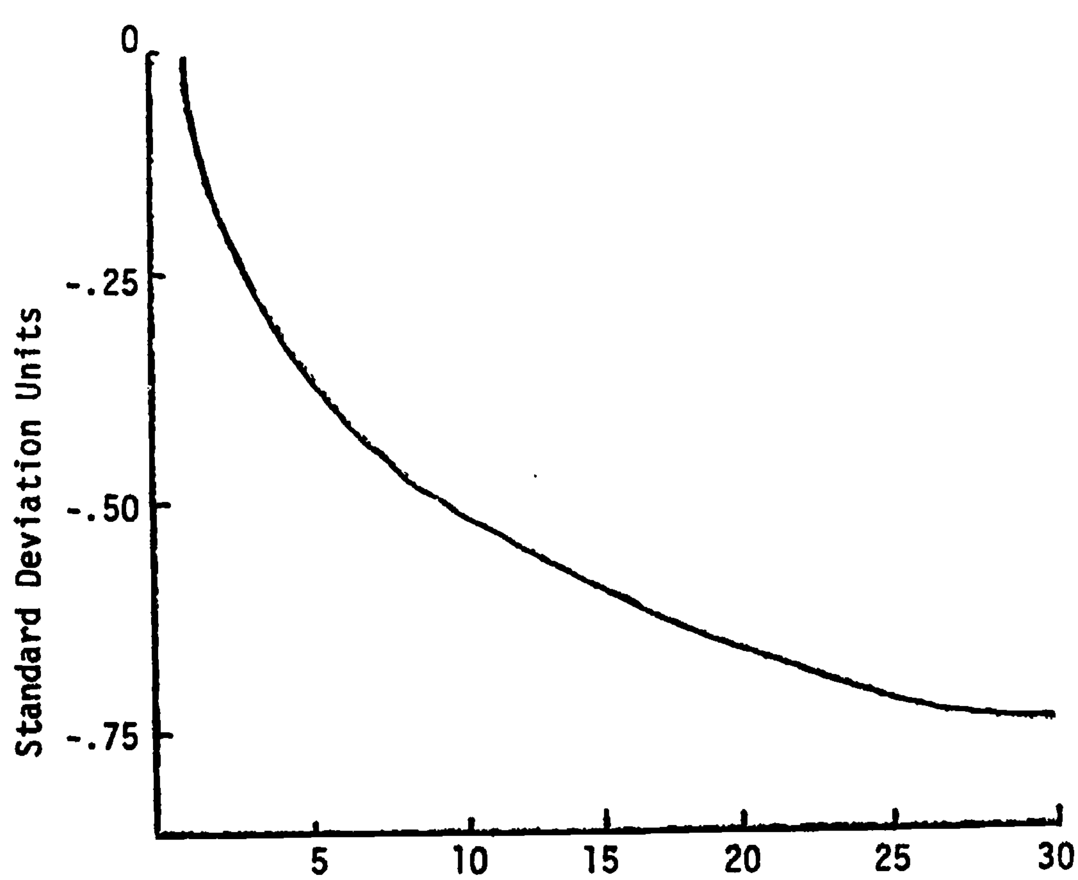


Figure 3. Data in Table 1 fitted to the log model of formula (2).

An Alternative Log Model.

A model may have advantages if it avoids highly interdependent data sets created (as in the first model) by taking all pairwise differences in a study. Such an alternative model can be developed along the following lines.

Let $\bar{y}_c$ and s_c be the mean and standard deviation of the dependent variable for class-size C in one of m studies. For the k class-sizes in a particular study, order the groups from $C_1 < C_2 \ldots < C_k$. Arbitrarily set

$$\delta_k = 0 \text{ ; then}$$

$$\delta_{k-1} = \frac{\bar{y}_{k-1} - \bar{y}_k}{(s_{k-1} + s_k)/2} ,$$

$$\delta_{k-2} = \delta_{k-1} + \frac{\bar{y}_{k-2} - \bar{y}_{k-1}}{(s_{k-2} + s_{k-1})/2} ,$$

$$\delta_{k-3} = \delta_{k-2} + \frac{\bar{y}_{k-3} - \bar{y}_{k-2}}{(s_{k-3} + s_{k-2})/2} \text{, and so on.} \tag{4}$$

The data from the fourteen class-size experiments have been scaled via formula (4) and are recorded in Table 2.

The following model can be postulated for data of the form in (4):

$$\delta = -\beta \log_e C + (\alpha_1 D_1 + \ldots + \alpha_m D_m) + \epsilon . \tag{5}$$

The $\alpha \cdot D$ terms in (5) represent dummy variables and arbitrary level parameters for the m separate studies; $D_i = 1$ if a δ in question comes from the ith study, and it equals zero otherwise. The parameters β and $(\alpha_1, \ldots, \alpha_m)$ can be estimated by regressing δ onto $\log_e C$. We have done so for the data in Table 2 and obtained a weighted least-squares estimate of β equal to 0.22. The estimates of the α's are unimportant. In this regression, each δ was

Table 2

Data on the Relationship of Class-size and Achievement from Studies Using Random Assignment of Pupils. (Outcomes scaled via Formula (4).)

Study Number	C, Size of Class	δ_c
1.	1.	.32
1.	25.	0
2.	1.	1.44
2.	3.	1.22
2.	25.	0
3.	17.	-.29
3.	[illegible]	0
4.	28.	-.03
4.	112.	0
5.	1.	.89
5.	2.	.53
5.	5.	.31
5.	23.	0
6.	15.	.17
6.	30.	0
7.	16.	.09
7.	23.	.04
7.	30.	0
7.	37.	0
8.	20.	.15
8.	28.	0
9.	26.	.29
9.	50.	0
10.	1.	.65
10.	32.	0
11.	15.	1.05
11.	37.	.65
11.	60.	0
12.	1.	.30
12.	8.	0
13.	15.	.07
13.	45.	0
14.	1.	.05
14.	14.	.17
14.	30.	0

weighted by k^{-1} so that each of the 14 studies would receive equal weight. The result is virtually identical to that obtained for the model in (3).

The model in (5) is more general and of more significance than the model in (3). Model (5) can be applied in a wide range of circumstances in which studies with quantitative independent variables are integrated. The first log term in (5) can be replaced by any mathematical function appropriate to a particular application. The important point about model (5) is that it simultaneously resolves the problems presented by different scales of measurement of Y and different values of X compared across studies.

Postscript

Estimating parameters of models in (3) and (5) is just the beginning of full data analyses aimed at integrating sets of studies with quantitative independent variables. Now residuals should be calculated, inspected and the models altered if trends in the residuals are observed.

We intend to compare the inferential properties of the models via jackknife methods to determine whether one has an advantage. It is unlikely that one is to be preferred to the other on grounds of better fit to the data; a proof of this fact may be possible.

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Glass, G.V and Smith, M.L. Meta-analysis of research on the relationship of class-size and achievement. Evaluation and Policy Analysis, 1979, 1, (in press).

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                ,F2.0,F1.0,2F2.0,3F1.0,2F2.0,F4.0,F1.0,2X,F1.0,F2.0,F4.2)
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COMPUTE         LOGLS=LN(LS)
COMPUTE         VARZ=V37*LOGLS
COMPUTE         VARY=LOGLS**2
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                STUDENT EFFECTS, TWO IS TEACHER EFFECTS, AND THREE IS INSTRUCTION
                AL EFFECTS
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VAR LABELS      V1,STUDY ID/
                V2,COMPARISON ID/
                V3,OUTCOME ID/
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                V21,ACCURACY OF ESTIMATE IN LARGE CLASS/
                V22,INSTRUCTOR TYPE/
                V23,SEX OF TEACHER/
                V24,YEARS OF TEACHING EXPERIENCE/
                V25,PUPIL ABILITY/
                V26,PERCENT FEMALE PUPILS/
                V27,AVERAGE AGE OF PUPILS/
                V28,STUDY SETTING/
                V29,ASSIGNMENT OF PUPILS TO GROUPS/
                V30,ASSIGNMENT OF TEACHERS TO GROUPS/
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                V32,PERCENT ATTRITION IN LARGE GROUP/
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                V34,OUTCOME CLASS/
                V35,METRIC OF MEASURE/
                V36,FOLLOWUP TIME/
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                TAGES (5)CORRELATIONS/
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                    V16 (1)LOW (2)MEDIUM (3)HIGH/
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FINISH

COMMENT THE FOLLOWING RECODE IS TO CLASSIFY OUTCOMES ACCORDING TO THE FIL BY SMITH SYSTEM WHERE ONE IS STUDENT ATTITUDES. TWO IS INDIVIDUAL IZATION. THREE IS STUDENT PARTICIPATION. FOUR IS ENRICHMENT. FIVE IS CLASSROOM BEHAVIOR. SIX IS INTERPERSONAL REGARD. SEVEN IS OPEN EDUCATION. EIGHT IS QUALITY OF INSTRUCTION. NINE IS TEACHER ATTIT UDE. TEN IS SCHOOL CLIMATE.

RECODE V33 (0101 THRU 0109=1)(0201 THRU 0209=2)(0301 THRU 0312=3)(0401 THRU 0406=4)(0501 THRU 0512=5)(0601 THRU 0605=6)(0701 THRU 0705=7)(0801 THRU 0810=8)(0901 THRU 0907=9)(1001 THRU 1003=10)

V33 (0101)STUDENT ATTITUDE TOWARD TEACHERS (0102)ST ATTITUDE TOWA RD SCHOOL OR CLASS (0103)ST. SELF CONCEPT (0104)ST MENTAL HEALTH (0105)ST ATTITUDE TOWARD EDUCATIONAL PROGRAM (0106)ST. MOTIVATION (0107)ST. PREFERENCES FOR CLASS SIZE (0108)ST ATTITUDE TOWARD LIFE (0201)TEACHER KNOWLEDGE OF PUPILS (0202)AMOUNT OF INDIVIDUAL TEACHER STUDENT INTERACTION (0203)NUMBER OR VARIETY OF ACTIVITIES (0204)AMOUNT OF SEATWORK OR STUDENTS WORKING ON INDIVIDUAL TASKS (0205)AMOUNT OF WORK IN SMALL GROUPS (0206)TEACHER ATTENTION TO I NDIVIDUAL STUDENTS (0207)ADAPTATION OF TEACHING TO INDIVIDUALS (0208)BUILDING FOUNDATION FOR INDEPENDENT WORK (0209)CONFERENCES WITH PARENTS (0301)STUDENT PARTICIAPATION IN DISCUSSIONS OR LESSO N(0202)AMOUNT OF INDIVIDUAL TEACHER STUDENT INTERACTION (0303 AMOUNT OF WORK IN SMALL GROUPS (0304)GENERATION OF AND RESONSE TO QUESTIONS (0305)INTEREST AND ENTHUSIASM FOR CLASSWORK (0206) ATTENDANCE (0207)STUDY HABITS (0308)TEACHER DIRECTEDNESS(-)(0309) STUDENT ENGAGEMENT (0310)DIFFICULTY IN LEARNING (0311)ATTENTION (0312)ON-TASK BEHAVIOR (0401)CREATIVE ACTIVITIES (0402)DRAMATICS (0403)DIVERGENT THINKING (0404)USE OF MANIPULATIVE MATERIALS (050 1)AGGRESSION (0502)OFFTASK BEHAVIOR (0503)APATHY (0504)FRICTION ((0505)DIFFICULTY (0506)DISCIPLINE (0507)DEPENDENCE (0508)ANXIETY (0509)AMOUNT OF TEACHER CONTROL (0510)POSITIVE TEACHER CONTROL (0511)GOOD STUDENT BEHAVIOR (0512)FRUSTRATION (0513)CHARACTER DEVELOPMENT (0601)PEER GROUP LINKS (0602)STUDENT SOCIAL INTERACTI ON (0603)COHESIVENESS (0604)FRIENDLY TEACHER STUDENT RELATIONSHIP (0605)SOCIOMETRIC CHOICE (0701)FREEDOM OF MOVEMENT IN THE CLASSRO OM (0702)STUDENT CHOICE OF ACTIVITIES (0703)INFORMALITY (0704)SOC IAL INTERACTION (0705 GOAL DIRECTION(-) (0(0801)CREATIVE INSTRUC- TION (0802)USE OF TEACHING AIDS (0803)TEACHER ORGANIZATION AND PLANNING (0804)GENERAL QUALITY (0805)AMOUNT OF MATERIAL COVERED (0806)TASK STRUCTURI NG (0807)POSITIVE EVALUATION (0808)VARIED LE ARNING ACTIVITIES (0809)INNOVATION (0901)TEACHER MORALE (0902)TEA CHER ATTITUDE TOWARD STUDENTS (0903)TEACHER PERCEPTIONS AND SATIS FACTION (0904)EXPECTATIONS FOR PERFORMANCE (0905)WORKLOAD (0906)A ABSENCES (0907)TEACHERCHER PROFESSIONAL GROWTH (1001GENERAL SCHOO L CLIMATE (1002)INNOVATIONS AND ADAPTATIONS IN THE SCHOOL (1003)U USE OF SPACE IN SCHOOL/