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ABSTRACT

Randomly assigned groups of fourth grade students were used to determine the effect of class size upon the learning of ten mathematical objectives. There were 20 groups of one, ten groups of two, four groups of five, and one group of 23 for each of three schools used in the study. Within schools, seven randomly assigned teachers presented the lesson and tested immediately after presentation. Students in each of the smaller class sizes displayed significantly greater attainment of the ten mathematical objectives than did those in classes with 23 students. Also, one-to-one instruction was significantly superior to one-to-five. (Author/JG)

THE EFFECT OF CLASS SIZE ON THE LEARNING OF MATHEMATICS: A PARAMETRIC STUDY

Although considerable research has been effected studying the relationship between class size and student achievement, these studies typically concentrate on the instruction of groups of 10 or more. In the present study 249 fourth grade Ss were randomly assigned to class sizes of 1, 2, 5, and 23. Ss in each of the smaller class sizes displayed significantly greater attainment of ten specific mathematical objectives than did students in the classes containing 23 Ss. In addition, one-to-one instruction was significantly superior to the one-to-five instructional settings. These results were considered to be of practical significance due to the increased resources available in many schools for individualization of instruction.

THE EFFECT OF CLASS SIZE ON THE LEARNING OF MATHEMATICS: A PARAMETRIC STUDY

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A substantial amount of research has been effected exploring the relationship between class size and student achievement. The overwhelming weight of this accumulated evidence points to the conclusion that the number of students within a given class has little influence on learning (Kidd, 1952; Stephens, 1967).

There are at least two considerations, however, which mitigate against accepting this evidence as final. The first is succintly discussed by Nachman and Opochinsky (1958) in a methodological study which demonstrated significantly greater learning in a class of 22 as compared to one containing well over 100 students. These authors suggested that classic class size research typically does not control for many variables irrelevant to the size of classes employed. For example, students who perceive that they are not learning a great deal in class might opt for more outside study, a behavior which could overcome an effect due to the independent variable. In order to control for this and other sources of error, the authors suggested that the dependent measure be administered immediately following instruction.

Secondly, previous research has seldom employed experimentally manipulated class sizes, a practice which has precluded both systematic variations in class sizes and examination of the effects of very small classes. Almost without exception class sizes of 15 or more have been employed, yet with the increased use of remedial personnel for academically deficient students as well as teacher aides within the classroom, smaller group instruction has become feasible in many settings. The present authors (Bausell, Moody, & Walzl, 1971) have demonstrated that one-to-one instruction results in greater mathematical learning than does classroom instruction. The present study was designed to explore the arameters of this effect by starting at a class size near that typically found in elementary schools and varying it downward to one-to-one instruction while partially controlling extraneous variables by testing immediately after instruction. A major purpose of this procedure was to determine if small class sizes other than the tutorial setting could result in increased learning. The effect of class sizes of 1, 2, 5, and 23 on the attainment of 10 specific mathematical objectives was studied.

Method

Subjects

The Ss were 249 4th grade students drawn from three elementary public schools in a Northern Delaware school district. Each participating school contributed 83 Ss.

Teachers

The teachers used in the study were 17 undergraduate junior and senior level elementary education majors who volunteered to participate. The study was conducted on three separate days with all but three teachers participating

on only one day in only one school. One teacher participated all three days in all three schools and two teachers participated on two days in two different schools.

Treatments. Within each school Group 1-1 consisted of 20 instructional trials in which one teacher instructed one S. Group 1-2 consisted of 10 instructional trials (within each school) wherein one teacher instructed two Ss simultaneously. Group 1-5 consisted of 4 trials with one teacher instructing five Ss, and Group 1-23 consisted on one instructional trial in which one teacher taught 23 Ss in a classroom setting.

The 83 Ss within each school were randomly assigned to the four treatment groups such that Groups 1-1, 1-2, and 1-5 each received 20 Ss while Group 1-23 received 23 Ss. The class size of 23 was dictated by the number of 4th grade Ss available in the smallest of the three schools.

Procedure. The study was conducted in three identical stages on each of three days over the course of a two week period. Thirty-five instructional trials were conducted on each of the three days progressing from School #1 on day #1 through School #3 on day #3. Seven teachers were employed in each school for five instructional units each.

Teachers volunteered to teach on specific days, hence were not randomly assigned to schools. Within each school, however, the seven teachers employed were randomly assigned to instructional units in the following manner: (1) all teachers were assigned to at least two Group 1-1 instructional trials, (2) all teachers were assigned to at least one Group 1-2 instructional trial, (3) no teacher was assigned more than one Group 1-5 instructional trial, and (4) no teacher was assigned both a Group 1-5 and a Group 1-23 instructional

trial. Trials were assigned in this manner to minimize variance between groups due to individual teacher differences.

The instructional order of each teacher's trials was randomly assigned with the constraints that (1) no two Group 1-5 instructional trials could be conducted simultaneously, and (2) no Group 1-5 instructional trial could be conducted at the same time that the Group 1-23 trial was being conducted. These constraints were necessitated by space limitations since Group 1-5 and 1-23 trials were conducted alone in a separate room. In each school three instructional trials were conducted in the morning and two in the afternoon.

One week prior to the beginning of the experiment each teacher was given a list of 10 specific instructional objectives accompanied by examples and brief mathematical discussions of each. No instructional methods nor techniques were suggested.

All 4th grade students in the three schools were pretested one day prior to instruction. In order to insure that Ss unfamiliar with the experimental unit were included in the experiment, only Ss attaining a score of five or less on the pretest were selected. This procedure resulted in elimination of less than 1% of the population.

On the day of the experiment Ss were taken from their regular classroom activities by the Es and placed in the charge of their assigned teacher in an isolated area within the school building. Each S was then instructed for exactly 30 minutes. Immediately following instruction all Ss were retested by an E in another area outside of their regular classrooms.

Test. The test consisted of 20 items: two items designed to measure each of the ten instructional objectives. The items were quite similar in content and

format to the examples given the teachers. For example objective 8 was:

Rename the product of two different factors with similar exponents as the product of the factors with the common exponent.

Example: $6^2 \times 7^2 = 42^2$.

The two test items measuring objective 8 were: 1) $6^1 \times 5^1 =$ _____

2) $2^5 \times 3^5 =$ _____

Split-half reliability for the 20 items using the Spearman-Brown formula was 0.89. The posttest correlated 0.55 with PMA IQ Scores.

Results

Table 1 summarizes the 3(schools) x 4(class size) analysis of covariance performed on the posttest scores using the pretest scores as the covariate.

Insert Tables 1 and 2 About Here

The class sizes studied strongly affected overall achievement of the 10 mathematical objectives [$F = 9.8$ (3,236), $p<.001$]. In addition class size interacted with the different school populations employed [$F = 2.4$ (6,236), $p < .05$]. Examination of Table 2 reveals that this interaction is due primarily to the instability of the Group 1-5 instructional setting in two of the schools, since with those exceptions, the means of the four class sizes are ordered perfectly within each school. Similarly, the grand means for each of the treatment groups are perfectly ordered with Ss receiving individual instruction (Group 1-1) registering the greatest learning gains and Ss in Group 1-23 the lowest. Neuman-Keuls comparisons (performed on adjusted means) indicated that learning in Group 1-1 was superior to all other class sizes [Group 1-2($p<.05$), Group

1-5($p<.01$), and Group 1-23($p<.01$)]. Although no difference in attainment of the 10 objectives between Groups 1-2 and 1-5 occured, both Groups 1-2($p<.01$) and 1-5($p<.05$) were significantly superior to Group 1-23.

It was hypothesized that the significant main effect [$F = 5.6$ (2,236), $p<.01$] which existed for the three schools was due to original nonequivalence of the school populations. To partially test this hypothesis, a 3 x 4 analysis of variance was performed on the 214 available IQ scores. The $F = 3.5$ (2,202), $p<.05$ obtained for the main effect for schools confirmed the hypothesis. Further, using the PMA measure, neither the class size main effect ($F<1$) nor its interaction ($F<1$) approached significance, indicating that the random assignment procedure had been successful.

Discussion

The results of the present study indicate that manipulation of class size does influence mathematical learning when that manipulation takes the form of reductions in size from an average class size standard. An examination of the absolute differences between the treatment group grand means reveals that the addition of one student to a one-to-one setting has almost twice the impact on learning efficiency as does the addition of three students to a one-to-two setting. Given this trend it is tempting to speculate that more statistical power would be required for a somewhat larger group than five students to prove incremental as compared to a group size of 23. Similarly, it would be surprising if small variations in class sizes over 20 would substantively affect achievement, but this is an empirical question.

The fact that only three teachers instructed Group 1-23 Ss certainly constitutes a threat to the generality of the findings. However, this weakness

is partially mitigated by the ordinal stability of all groups with the exception of 1-5 across the three replications (schools), as well as the fact that the Group 1-1 versus 1-23 comparison is a replication of a previous study by the present authors. The overall instability of individual instructional trials, however, points to the need for a more thorough mapping of the parameters of class size, especially of instructional settings larger than 1-2 and smaller than 1-20.

Conclusions

Given the limitations of the present study, the finding that learning varies with individualization of instruction has both practical and theoretical significance. An empirical rationale is supplied for small group remedial instruction in those cases in which additional personnel are available to supplement the instruction of the classroom teacher. Examination of the means of the four groups, however, clearly indicate that although small group instruction is incremental when compared to large group instruction, large group instruction is much more efficient in terms of total learning produced. For this reason it is tempting to suggest that personnel such as teacher aides might be efficaciously employed to instruct small groups of academically needy students at the same time that the regular classroom teacher instructs the remaining students. Such a procedure should result in decreasing the deficiencies of the students instructed in the small groups, since teacher training and experience do not appear to affect student achievement (Moody and Bausell, 1971). The procedure might even prove two-edged since the larger group instructed by the classroom teacher would be smaller than normal, less the students being instructed in small groups.

The phenomenon is theoretically important because of the unanswered question: why should students learn more in small groups than large ones when the curriculum and instructional time are held constant? The obvious answer is that effective instructional time is increased by individualization. It is not quite so obvious how this is accomplished, although a modified interaction analysis might prove an efficient procedure for exploring the question.

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Table 1

Analysis of Covariance Summary Table for Posttest Scores

Source	df	ss	ms	F
A [schools]	2	188.37	94.19	5.57**
B [class size]	3	498.34	166.11	9.82***
AB	6	244.06	40.68	2.40*
w/cells	236	3992.76	16.92	
Total	247	4923.53		

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

Table 2

Means* and Standard Deviations for Posttest Scores

		School #1	School #2	School #3	Total
Group 1-1	$\bar{X}$	10.25	12.30	12.20	11.58
	$\bar{X}$(adj.)	*10.69*	*11.83*	*11.98*	*11.50*
	S.D.	5.84	4.60	4.47	5.01
Group 1-2	$\bar{X}$	9.65	10.40	9.95	10.00
	$\bar{X}$(adj.)	*9.83*	*10.33*	*10.03*	*10.07*
	S.D.	4.37	3.86	3.50	3.75
Group 1-5	$\bar{X}$	8.10	7.35	11.85	9.10
	$\bar{X}$(adj.)	*8.54*	*7.28*	*11.88*	*9.23*
	S.D.	4.06	4.84	4.19	4.56
Group 1-23	$\bar{X}$	5.26	8.83	9.22	7.75
	$\bar{X}$(adj.)	*5.32*	*8.75*	*9.08*	*7.65*
	S.D.	3.70	4.19	3.69	4.21

*Adjusted means are italicized.

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