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ABSTRACT

This meta-analysis investigates the effects on achievement of type of graphing paper employed in displaying student performance data collected over time. Ongoing curriculum-based measurement systems employing Data-Based Program Development (DBPD) provide a data source of 16 controlled studies with 17 effect sizes. A total of 3,494 subjects participated in these studies, with 81 percent of the investigations employing handicapped subjects. The average weighted unbiased effect sizes for six-cycle and equal interval paper, respectively, were .65 and .46. Hedges' analogue to analysis of variance indicated this difference was not statistically reliable. This study provides a basis for two conclusions: (1) the existing data base concerning methods for displaying student performance data indicates that type of graphing method does not affect student achievement reliably; and (2) this meta-analysis highlights the need for components of DBPD, including graphing conventions, to be contrasted within the context of controlled experimental investigations. Comparisons of DBPD components within controlled experimental studies should provide important knowledge about critical elements of ongoing monitoring systems for effective development of individualized instructional programs. Implications for special education practice are discussed. An appendix lists the reports included in the meta-analysis. (Author/PN)

Effects of Alternative Student Performance Graphing Procedures on Achievement

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Running Head: Graphing Procedures

Abstract

This meta-analysis investigated the effects on achievement of type of graphing paper employed in displaying student performance data collected over time. The data source was 16 controlled studies with 17 effect sizes. The average weighted unbiased effect sizes for 6-cycle and equal interval paper, respectively, were .65 and .46. Hedges's analogue to analysis of variance indicated this difference was not statistically reliable. Implications for special education practice are discussed.

Individualization, in which the pacing and method of instruction are varied to match students' needs (Glaser & Nitko, 1971), is a popular notion in special education (see Corrigan, 1978; Council for Exceptional Children Delegate Assembly, 1983; Mann, Suiter, & McClung, 1980), and Federal law (PL 94-142) mandates that an individualized educational program be devised for each handicapped pupil. The traditional strategy for developing such programs is an aptitute-treatment interaction approach, whereby norm-referenced measures are employed to diagnose students' ability profiles, and then educational programs are matched to those profiles and prescribed as treatments. While such a diagnostic-prescriptive approach is prevalent even today (Carbo, 1983), evidence accumulated over the past 15 years indicates that it fails to contribute to differentially effective learning rates (Arter & Jenkins, 1977, 1979; Hammill & Larsen, 1974; Hammill & Weiderholt, 1973).

As an alternative to this diagnostic-prescriptive strategy for generating individualized instructional programs, ongoing curriculum-based measurement systems have been developed (Deno & Mirkin, 1977; Lindsley, 1977; Lovitt, 1977; Mirkin et al., 1981; White & Haring, 1980). With these systems, hereafter referred to as Data-Based Program Development (DBPD), initial educational plans are viewed as hypotheses concerning effective treatment. Therefore, during treatment implementation, data are collected in an ongoing manner, graphed, and analyzed to evaluate hypotheses and revise and improve programs. This leads to empirically derived and validated individualized educational programs (Deno & Mirkin, 1977).

Evidence indicates that the use of DBPD improves student learning. Fuchs and Fuchs (in press) reported an average effect size of .70 for students whose programs were developed systematically and empirically over time. This indicates that, in terms of the standard normal curve and an achievement test scale with a population mean of 100 and a standard deviation of 15, the use of DBPD can be expected to raise the typical achievement outcome score from 100 to 110.50, or from the 50th to 76th percentile.

One DBPD component associated with student achievement is graphing. When student data are charted rather than simply recorded, achievement improves approximately .50 of a standard deviation (Fuchs & Fuchs, in press). In fact, within DBPD specifically and applied behavior analysis generally, agreement prevails that graphing is critical: It assists in organizing data for formative evaluation, provides a detailed numerical summary and visual description of performance, and facilitates communication of program results (Tawney & Gast, 1984).

Despite concurrence on the importance of graphing, salient differences exist concerning specific graphing conventions, including the type of paper employed. Some programs advocate the use of ratio or logarithmically scaled graph paper (e.g., Lindsley, 1977; White & Haring, 1980), where the rate scale is adjusted to display proportional changes in student behavior. For example, the change from 10 to 20 is identical in distance to the change from 20 to 40 or from 40 to 80. In contrast, developers of other DBPD systems support the use of equal interval, or conventional, graph paper (e.g., Deno & Mirkin, 1977).

In selecting between alternative DBPD procedures, such as graphing paper, three basic considerations are technical properties, logistical features, and effects on student achievement (Deno, Mirkin, & Fuchs, 1982). Available research and competing arguments for each consideration relevant to the two types of graphing paper are presented below.

Technical Properties

Proponents of logarithmically scaled paper contend that an important justification for this graph paper is technical; that is, the ratio scale more accurately reflects the proportional way in which natural change occurs than does equal interval paper (White & Haring, 1980). Yet, findings of the only identified, relevant, empirical contrast of the two graphing methods fail to support this contention. Specifically, Marston (1982) compared the prediction capabilities of logarithmic and conventional charts. He collected weekly performance data in reading, spelling, and written expression for 10 weeks. Then, he charted student performance data over weeks 1 through 7 on equal interval and on ratio scaled paper. Next, based on the trends indicated on each graph, he calculated predictions concerning performance during weeks 8 through 10. Finally, he compared each prediction to actual student performance for weeks 8 though 10 and found that, for each academic area, predictions were significantly better when based on the equal interval, rather than the ratio scaled, graphs. This finding tentatively suggests that change in these academic areas occurs additively rather than proportionately, questioning the basic technical rationale for the use of logarithmic paper.

Logistical Features

Regarding logistics, two basic arguments exist, one supporting each type of graphing method. Proponents of the logarithmic approach purport that the corresponding paper is logistically superior because a single chart can be used to display all relevant behaviors, given the large behavior range covered on one graph, and relatedly, that a standard chart can facilitate comparisons among different behaviors (White & Haring, 1980). On the other hand, some contend that equal interval graphs facilitate data analysis (Tawney & Gast, 1984), basically are easier for students and teachers to understand, and that this understanding may lead to more consistent implementation of DBPD (Mirkin, Fuchs, & Deno, 1982). Despite this controversy surrounding the relative logistics associated with the types of graphing paper, we know of no empirical contrast of teacher and student concerns. Therefore, there is no objective basis to support the relative logistical merits of either graphing approach.

Effects on Achievement

Despite continuing disagreement concerning which type of graph method is technically and logistially superior, there has been relatively little attention directed toward which type of graphing method leads to improved student achievement. In a search for relevant findings, only one related report was identified. Brandstetter and Merz (1978) conducted a series of two studies. The first compared gains made while charting scores on linear graphs with gains made while simply recording raw scores. The second compared gains associated with charting scores on ratio scaled graphs with those related to the simple recording of raw scores. Unfortunately, no attempt was made to compare the effectiveness of graphing on linear and ratio scaled graphs. Furthermore, the children employed in the two studies were neither randomly assigned nor similar to each other, making it impossible to draw valid comparisons between the educational effects of the two types of graphs.

Therefore, the currently available data base for selecting the superior graphing method is inadequate. Only one study addresses the prediction capabilities of the methods, with little available information concerning other technical properties, and there is no data base on the relative logistical strengths and weaknesses of the methods. Moreover, the data base concerning the most important criterion for selecting a type of graphing method, effect on student achievement, is scant. Nevertheless, a diverse literature on educational effects of DBPD programs, in general, is available. The methodology of meta-analysis allows for the comparison of effects across different studies along the factor graphing method. Consequently, the purpose of the current investigation was to conduct a meta-analysis of the effect of graphing method on academic achievement. Such an analysis should clarify whether these two well known approaches contribute differentially to student achievement.

Method

Search Procedure

The search for pertinent studies to include in the meta-analysis comprised four steps. First, employing the Thesaurus of Psychological Index Terms (APA, 1982), multiple descriptors were generated for key topic-related terms. For example, student achievement alternately was represented by "student progress" and "educational effects." Second, these terms facilitated a computer search of three on-line data bases: (a) ERIC, a data base of educational materials from the Educational Resources Information Center consisting of abstracts from Research in Education and Current Index to Journals in Education; (b) Comprehensive Dissertation Abstracts; and (c) Psychological Abstracts. Third, employing similar key descriptors, a manual search was conducted of five educational journals for the years 1973 to present. These journals were: American Educational Research Journal, Journal of Learning Disabilities, Journal of Precision Teaching, Journal of Special Education, and Learning Disability Quarterly. Fourth, titles in the reference sections of investigations discovered by these efforts were explored for additional studies.

Criteria for Relevant Studies

A study was considered for inclusion if it employed a control group to evaluate the effects of DBPD on the academic performance of elementary and/or secondary students. DBPD was defined as curriculum-based data collection that occurred at least twice weekly, with decisions concerning the adequacy of programs formulated on an individual, not group, basis. Studies were excluded that (a) monitored nonacademic behaviors, (b) primarily focused on the use of behavior modification, while employing time series to test experimental effects, (c) provided test feedback only to students, and/or (d) employed preschool or college-age subjects.

The search yielded 28 studies that met the criteria established for inclusion. From these studies, 12 were eliminated because of insufficient data for calculating effect sizes, leaving 16 studies that were employed in the analyses described below.

Data Extracted from Each Study

Guidelines were established to ensure that each relevant effect size was counted only once in analyses, and that different papers reporting results of the same study were grouped within analyses as one investigation.[1]

Results of the studies were transformed to a common metric, effect size, defined here as the difference between the treatment means, divided by the control group standard deviation. For purpose of analysis, an effect was given a positive sign if subjects achieved greater scores in the DBPD treatment. For studies reporting relevant means and standard deviations for both groups, effects sizes were calculated from these measurements. For studies not reporting means and standard deviations, effect sizes were calculated from other statistics such as F or p values (see Glass, McGaw, & Smith, 1981). When pretest differences or analyses of covariance were reported, alternative procedures for calculating effect size were used, as possible, to control for initial student differences.

Each effect size was converted to an unbiased effect size (UES) to correct for inconsistency in estimating true from observed effect sizes (Hedges, 1981). The difference between the observed and UESs was neglible ($X = .019$, $SD = .025$) as has been demonstrated elsewhere (Bangert-Drowns, Kulik, & Kulik, 1983). Nevertheless, UESs were employed to insure the mathematical tractability of the data.

Data aggregation. UESs were aggregated at the study level for different types of graphing method. Therefore, one UES per study was reported (with the exception of the Brandstetter and Merz [1972] article for which there was one effect size for equal interval and one for ratio scaled paper). In aggregating these UESs for a measure of central tendency for each type of graphing method, weighted averages were calculated to account for the variance of the UESs (see Hedges, 1984).

To describe study features pertinent to the current investigation, the type of graphing method employed in each study was identified and coded. This variable had two levels, equal interval paper and ratio scaled paper. Two coders independently coded 10 of the 16 studies (63%). Percentage of agreement[2] for the coders was 100. A previous investigation (Fuchs & Fuchs, in press) explored methodological quality of the studies and identifed no relation between effect size magnitude and study quality.

Characteristics of the Sample

Of the 18 references in the Appendix, which represent 16 separate investigations, there are 4 dissertations, 9 unpublished studies, and 5 journal articles. Among the published papers, 2 appeared in Exceptional Children, 2 in American Educational Research Journal, and 1 in American Journal of Mental Deficiency. A total of 3494 subjects particiated in these studies, with 81% of the investigations employing handicapped subjects. Of these handicapped pupils, 91% were mildly to moderately handicapped and 9% were severely handicapped. The grade level of these subjects ranged from 1 through 12, with a median grade level of 3.85. Among the 16 investigations, 7 (44%) focused solely on the area of reading, 3 (19%) on reading and math, 2 (13%) on math alone, and 1 (6%) each on (a) spelling, (b) high school content areas, (c) reading and spelling, and (d) reading, math, and spelling.

Results

Sixteen studies with 17 associated mean effect sizes were identified for the meta-analysis. These studies with associated average effect sizes are presented in Table 1. Of these UESs, 7 were related to equal interval graph paper and 10 were associated with ratio scaled paper.

To examine the relation between UES and type of graphing method, Hedges's (1984) chi-square analogue to analysis of variance was employed. When conventional analysis of variance is conducted on effect sizes, problems exist because of the possibility that systematic variance will be pooled into the estimate of error variance. Moreover, violation of the homoscedasticity assumption is severe in research synthesis, and there is little reason to believe that the usual robustness of the F test will prevail (see Hedges, 1984). Thus, Hedges's analogue to analysis of variance was employed to avoid these conceptual and statistical problems.

Results revealed no significant effect, $\chi^2(1, N = 17) = 3.6$, ns, indicating no reliable difference in achievement between the different graphing methods. For equal interval paper, the mean weighted UES was .46, with a variance of .0092. This mean UES was, itself, statistically significantly different from zero, $z = 4.79$, $p < .001$. For ratio scaled paper, the mean weighted UES was .65, with a variance of .0016. This mean UES also was statistically significantly different from zero, $z = 16.25$, $p < .001$.

Insert Table 1 about here

Discussion

DBPD represents an effective alternative strategy for developing individualized instructional programs for special education students (Fuchs & Fuchs, in press). Moreover, graphing student performance data is a critical component of effective DBPD (Fuchs & Fuchs, in press). Nevertheless, previous research fails to provide an adequate data base for determining whether a type of graphing method is superior for displaying and evaluating data within DBPD. Therefore, the purpose of this study was to integrate quantitatively the available research on DBPD to assess the effect of type of graph paper on student achievement.

Results indicated that type of graphing method employed to display student performance data did not produce a statistically significant effect on student achievement. Additionally, the difference between the mean effect sizes associated with the graphing methods is of little practical importance (Cohen, 1977): The weighted mean effect size for ratio scaled paper was approximately .2 of a standard deviation higher than the weighted average effect size associated with equal interval paper. This indicates that, in terms of the standard normal curve and an achievement test scale with a population mean of 100 and standard deviation of 15, one might expect the use of ratio scaled gaph paper to raise the typical achievement outcome a relatively small degree, from 100 to 103.

Therefore, this study provides a basis for two conclusions. First, the existing data base concerning methods for displaying student performance data indicates that type of graphing method does not affect student achievement reliably. Consequently, as practitioners design systematic formative evalation procedures with which to formulate individualized educational programs, they may employ personal preferences and logistical considerations. Second, this meta-analysis highlights the need for components of DBPD, including graphing conventions, to be contrasted within the context of controlled experimental investigations: Whereas meta-analysis serves to integrate and quantify effects across studies of different methodology and conceptualization, it is possible for systematic variations to occur between groups of studies constituting important contrasts. Therefore, comparisons of DBPD components within controlled experimental studies should provide important knowledge about critical elements of ongoing monitoring systems for effective development of individualized instructional programs.

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Footnotes

[1] One paper authored by Haring (1971) and two additional reports by Haring & Krug (1975a, 1975b) described aspects of the same investigation. Therefore, although it is reported that 16 studies were employed in the meta-analysis, 18 appear in the Appendix due to the separate listing of the Haring and the Haring and Krug papers.

[2] Percentage of agreement was calculated using the following formula (Coulter cited in Thompson, White, & Morgan, 1982): Percentage of agreement = agreements between observer A & observer B/(agreements between A & B + disagreements between A & B + omissions by A + omissions by B).

Table 1

Study Citations and Weighted UESs by Graphing Convention

Graphing Convention/Citation	Weighted UES
Equal Interval Paper	
King, Deno, Mirkin, & Wesson (1983)	- .37
Tindal, Fuchs, Christenson, Mirkin, & Deno (1981)	- .09
Skiba, Wesson, & Deno (1982)	.21
Mirkin (1978)	.43
Mirkin, Deno, Tindal, & Kuehnle (1980)	.86
Fuchs, Deno, & Mirkin (1984)	1.00
Brandstetter & Merz (1978)	1.06
Six-Cycle Paper	
Brandstetter & Merz (1978)	.13
Frumess (1973)	.21
Beck (1981b)	.33
Beck (1979)	.45
Beck (1976)	.48
Beck (1981a)	.50
Haring (1971)/Haring & Krug (1975a, 1975b)	1.04
Dubrule (1984)	1.18
Bohannon (1975)	1.58
Bruening (1978)	1.99

Appendix

Reports Included in the Meta-Analysis

Beck, R. (1976). *Report for the Office of Education dissemination review panel.* (Unpublished manuscript available at Precision Teaching Project, 3300 Third St. N.E., Great Falls, MT 59404.)

Beck, R. (1979). *Report for the Office of Education dissemination review panel.* (Unpublished manuscript available at Precision Teaching Project, 3300 Third St. N.E., Great Falls, MT 59404.)

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