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AUTHOR Elfner, Eliot S.
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ABSTRACT

Alternative techniques for analyzing student outcomes were investigated. Two traditional statistical methods (one-way analysis of variance and two-way analysis of variance) were compared with an innovative input-output analysis. The input-output analysis is a two-step analysis consisting of a regression analysis to determine the relationships among input and output variables and an analysis of variance of the residuals grouped by treatment to determine treatment effect. Student outcome data used in the study were generated in a typical classroom experiment comparing three different methodologies of presenting material to students. Pre- and post-measures of student achievement on a final exam were taken. Some measures of student input characteristics, including grade point average, age, sex, year in school, and residential status, were also taken. While the traditional analysis techniques failed to show any treatment effects, the input-output technique showed one of the treatments to be superior to the others. It is suggested that the traditional analysis of change scores in experimental research may not be directly applicable to most research conducted on students. The treatment effects on student outcomes may well be a function of input characteristics and an interaction over time for individual students, which are not always discernable with traditional statistical analysis techniques. However, the input-output analysis allows for these problems by including other input characteristics in the analysis and allowing for the separation of data by individuals. It is concluded that student outcome research could benefit from the application of the input-output technique. (SC)

A Comparative Study of Alternative Techniques for Analyzing Student Outcomes

By

Eliot S. Elfner, Ph.D.
Associate Professor of
Business Administration
St. Norbert College
De Pere, WI 54115

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ABSTRACT

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Eliot S. Elfner, Ph.D.
Associate Professor of
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St. Norbert College
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This paper has suggested that the traditional analysis of change scores in experimental research is not directly applicable to most research conducted on students. The treatment effects on student outcomes may well be a function of input characteristics and an interaction over time for individual students, and such effects are not always discernable with traditional statistical analysis techniques. However, an analysis technique known as the input-output technique allows for these problems. The results of a classroom experiment are presented in three separate analyses--one-way analysis of variance, analysis of variance with repeated measures, and the input-output technique originally applied widely by Astin. It is shown that the traditional analysis techniques fail to show any treatment effects. However, the input-output technique does show one of the treatments to be superior to the others. This is explained to be the result of including input characteristics in the analysis, which are not accounted for in the traditional analyses. It is concluded that most research having to do with student outcomes would benefit from the application of the input-output technique.

Introduction:

Colleges and universities have been confronted with the necessity of justifying their programs more and more during recent years. This author has elsewhere presented the development of this thrust with the restricted funds currently available.[1] It must be possible to demonstrate that the objectives for which a particular program is offered are being achieved.

When the objectives of the programs offered by a particular college or university are focused on the development of student abilities, knowledge, attitudes, or characteristics, the effectiveness of that program will best be demonstrated by student outcomes which show improvement on desired criteria. Student outcomes become, therefore, very important in evaluating program effectiveness.

The measurement of student outcomes has often been attempted. Many researchers have developed various instruments designed to measure certain student characteristics.[2] These measures are often quantitative in nature, providing objective, numerical data indicating student performance on the particular criteria being assessed. This leads to an approach in program evaluation which

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[1]Elfner, Eliot S., The Use of Student Outcomes in the Planning and Resource Allocation Component of the Administrative Decision-Making Process in Higher Education, Unpublished Dissertation, University of Wisconsin-Madison, 1977.

[2]For a review of most of the current instruments used for measuring student outcomes, see Chapter Two of Elfner, Eliot S., The Use of Student Outcomes., Ibid.

emphasizes the statistical analysis of measured data.[3] Such quantitative information provides administrative decision-makers with some systematic data with which to judge program effectiveness. It should be recognized, however, that the systematic data is only one of several inputs to the decision-making process. Program effectiveness should be determined from a combination of both qualitative and quantitative inputs.

The use of quantitative measures of student outcomes in program evaluation emphasizes a statistical approach. Most instances of statistical analyses employ a simple research design, coupled with traditional statistical analyses, requiring the aggregation of individual change scores in pre- and post-measures of the desired criterion, with an intervening treatment. This treatment is usually the program being evaluated. The impact of the program on the desired student outcome, as determined by the criterion measure, is analyzed to determine program effectiveness.

It has been argued elsewhere that such traditional analyses of student outcomes results in failure to assess certain very pertinent questions about program effectiveness.[4] There is a major question regarding the effect of incoming student characteristics in interaction with the program treatment. It can often be

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[3]For a discussion of the quantitative and qualitative methods of program evaluation, See Pace, C. Robert, and Jack Friedlander, "Approaches to Evaluation: Models and Perspectives," In New Directions for Student Services: Evaluating Program Effectiveness, Issue No. 1, Spring, 1978, PP. 1-18.

[4]See for instance, Elfner, Eliot S., "Analysis Techniques for Assessing the Effect of Higher Education on Student Development Outcomes," paper presented to the Association of Institutional Research Nineteenth Annual Forum, May, 1979, San Diego, Ca.

asserted that results of the program are a function of the incoming students rather than the treatment of the program, and that in fact the program has little or no effect on the student outcomes being measured.

Another question raised about the traditional analyses has to do with the ceiling and floor and regression effects. traditional research designs used in the analysis of student outcomes often raise more questions than they answer. It is the purpose of this paper to address several methods of analyzing student outcome data, providing an example of some real student outcome data collected in a traditional classroom situation.

Three separate analysis techniques will be presented. The first two are traditional statistical methods - one-way and two-way analysis of variance.[5] The other technique to be presented is called input-output analysis.[6] Student outcome data for this paper were generated in a typical classroom experiment comparing three different methodologies of presenting material to students. Pre- and post- measures of student achievement on a 75 item final exam were taken. Also, measures of other student input characteristics, such as grade point average, age, sex, year in school, and residential status (dorm resident vs. off campus resident) were taken.

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[5]For a detailed presentation of these two techniques, see Hay, William L., Statistics for the Social Sciences, 2nd ed., Holt, Rinehart, and Winston, Inc., (New York, 1973), Chapters 12 and 13.

[6]For a detailed description of the input-output analysis technique and its benefits, see Elfner, Eliot S., "Analysis Techniques for Assessing ..", Op. cit., pp. 5-7

The following is a presentation of each of the three analysis techniques. The statistical significance of the results of each leads to different conclusions. A discussion of the implications of these different conclusions follows. Finally, a judgement is made about the most appropriate analysis technique for use in program evaluation.

Description of Analyses:

The experiment which was undertaken for this study consisted of three experimental groups. Each member of all three groups was measured on several characteristics to establish comparability among the three groups. Characteristics measured included academic major, sex, residential arrangements, age, and grade point average. CHI square and one-way analysis of variance resulted in no significant differences among the groups.

A one-way analysis of variance was conducted on the post-test scores. Figure One presents the Anova Table.

SOURCE	D.F.	SUM-OF-SQUARES	MEAN-SQUARES	F-RATIO
Between Groups	2	287.50	143.75	2.29
Within Groups	116	7288.19	62.83	
Total	118	7575.69		

XBAR(1) = 48.98 XBAR(2) = 45.46 XBAR(3) = 45.98

FIGURE ONE

ONE-WAY ANALYSIS OF VARIANCE TABLE

The F-ratio associated with the above analysis of variance leads one to conclude that there is no significant variance among the three groups on the student achievement measure. A researcher using this traditional approach to analyzing student outcomes is likely to infer that the differential treatments cause no significant effects on student outcomes. It will be shown that this is not necessarily the proper conclusion.

An analysis of variance and co-variance including repeated measures was also conducted. Figure Two presents the results of that analysis.

SOURCE	SUM-OF-SQUARES	D.F.	MEAN SQUARE	F-RATIO
Grand Mean	386864.56	1	386864.56	5320.58
Group	215.91	2	187.96	1.48
Error	8434.47	116	72.71	
Pre-Post	8899.11	1	8899.11	387.64
Pre-Post Group	101.55	2	50.77	2.21
Interaction Error	2663.01	116	22.96	

FIGURE TWO

ANALYSIS OF VARIANCE AND CO-VARIANCE INCLUDING REPEATED MEASURES

Once again, the statistics lead one to conclude that neither of the main effects, nor any of the interaction effects are significant. Such results would imply that the treatments had no differential impact on the students' learning. It will be shown that this, too, may not be an accurate conclusion.

Both of the above analysis techniques require the aggregation of data gathered from individuals. This aggregation process masks the individual changes which result from the experimental treatments. Individuals change as a result of both treatment effects and the interaction of the treatment effects with characteristics which they themselves bring to the experimental environment. An analysis technique which accounts for the effect of these input characteristics, as well as the treatment effects, would account for these questions. The researcher would then be able to more accurately assess the effects of the experimental treatment. The input-output technique introduced above provides the ability to account for both input and treatment effects. A description of the application of this analysis technique to the same data as analyzed above follows.

The initial task in applying the input-output technique is to regress the outcome variable on the relevant input data for all participants in each of the three experimental groups. In this example, the post-test scores were regressed on the pre-test scores, and several other potentially relevant input variables. Included among these were grade point average, a measure of motivation to study for the post-test, and age. The results of the regression included only the pre-test and grade point average as significant input variables. The coefficient of determination for the regression was 0.43.

The next step in this technique is to calculate the residuals for each participant. First the expected post-test score is calculated using the regressed model, and then subtracted from the participant's actual post-test score. These residual scores are identified with each participant, and reflect both their knowledge when entering the treatment as well as the effect of the treatment. To the extent that the residuals of participants from one group differ from those of others, effects can be attributed to that treatment. By grouping the residuals of participants by treatment, simple one-way analysis of variance of the residuals can be conducted. To the extent that significant results are found, the treatment can be said to be effective.

For the data in this study, the residuals here calculated for each participant, and grouped by treatment. The analysis of variance resulted in a significant F score. Figure Three presents the Anova Table for the residuals.

SOURCE	SUM OF SQUARES	D.F.	MEAN SQUARES	F-RATIO
Between	5.04	2	2.52	4.71
Within	62.00	116	0.53	
Total	67.04			

X-BAR(1) = 0.278 X-BAR(2) =-0.129 X-BAR(3) =-0.168

FIGURE THREE
ANALYSIS OF VARIANCE OF RESIDUALS

The results of this analysis clearly suggest that the first treatment group is effected more by the experimental activity than either of the other two treatments. Since the residuals from all participants seem to be randomly distributed, it is clear that the systematic grouping by treatment is significant.

Conclusions:

The results of the above analyses demonstrate that the typical approach to analyzing change scores can lead to findings which are not necessarily accurate. This occurs because of two primary faults with these traditional approaches. First, the data are aggregated, leading to a loss of information relative to individual subjects. Only the aggregated data are manipulated in the statistical analyses. Second, the input characteristics of subjects must either be assumed to be randomly distributed, or matched. This kind of assumption is appropriate when subjects can be randomly chosen, or chosen to be matched. However, when subjects are self-selected into the treatment groups, as is often the case when conducting classroom experiments, and other research related to student outcomes, it is not possible to assure that the input characteristics of students in the experimental groups are matched on all relevant dimensions. Even when choosing subjects for matching the several experimental groups, the finite nature of the group size often precludes accurate matching on all relevant input characteristics. Therefore, in order to account for the differential input characteristics of subjects in most research on student outcomes, an analysis technique which minimizes the loss of information about subjects seems to be called for.

The three analyses presented above seem to demonstrate the superiority of the input-output analysis technique. Because it clearly provides for both the separation of data by individuals, and for the input characteristics of subjects, it accounts for a more accurate assessment of the actual changes which occur due to the experimental treatments.

The input-output analysis technique does require certain extra work. By nature, it is a longitutinal assessment technique. It requires the collection of data from subjects to be linked to each individual. In addition, it is a two-step analysis -- first a regression analysis to determine the relationship among input and output variables, and then an analysis of variance of the residuals grouped by treatment to determine treatment effect. These extra demands on the researcher are the major disadvantages of the input-output analysis technique. It is suggested that in order to better account for the differences in individual characteristics in most research dealings with student outcomes, the preferred technique is the input-output analysis approach. The above analyses suggest that results of traditional analyses may differ from those secured from the input-output analysis.

This paper has suggested that the traditional analysis of change scores in experimental research is not directly applicable to most research conducted on students. The treatment effects on student outcomes may well be a function of input characteristics and an interaction over time for individual students, and such effects are not always discernable with traditional statistical analysis techniques. However, an analysis technique known as the input-output technique allows for these problems. The results of a classroom experiment are presented in three separate analyses --one-way analysis of variance, analysis of variance with repeated measures, and the input-output technique originally applied widely by Astin.[7] It is shown that the traditional analysis techniques fail to show any treatment effects. However, the input-output technique does show one of the treatments to be superior to the others. This is explained to be the result of including input characteristics in the analysis, which are not accounted for in the traditional analyses. It is concluded that most research having to do with student outcomes would benefit from the application of the input-output technique.

[7]Astin, Alexander M., "Measuring Student Outputs in Higher Education," in the Outputs of Higher Education: Their Identification, Measurement, and Evaluation. Lawrence, Ben, et. al., eds., Boulder, Colorado, National Center for Higher Education Management Systems at the Western Interstate Commission for Higher Education, 1978.

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