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ABSTRACT

The use of of the Automatic Interaction Detector (program AID3 of the OSIRIS statistical package) to study a university program is discussed. The performance of students who took general physics lecture and laboratory concurrently is compared to the performance of those who took them separately. Five years of data are analyzed, covering 1,997 students. The educational outcomes investigation uses the AID3 program to examine a variety of independent variables, including Scholastic Aptitude Test (SAT) scores, physics lecture grade, student major, student level, high school rank, and student sex. The AID3 analysis indicates that the importance of the concurrent laboratory depends strongly on when in the analysis it is considered. The demographic measures that make a difference in explaining grades in physics class include: overall grade average, SAT math score, high school rank, and the year in which the student took the course. Finally, some nonadditive interactions occur in the data. It is demonstrated that the research method allows researchers to consider a large number of variables as possible explainers of course performance without making the restrictive assumptions required by other techniques. (SW)

"AID"-ING ACADEMIC PROGRAM EVALUATION
The "Automatic Interaction Detector" As Analysis Tool

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Abstract

An educational outcomes study is among the least amenable to traditional statistical methods. Selection of dependent variables can mean cell sizes too small for significance or it can mean too simplistic an analysis. The "Automatic Interaction Detector," program AID3 of the OSIRIS package, permits analysis of explanatory variables without assuming that interactions are additive or that important interactions are with variables already in the model. This paper demonstrates the use of AID3 in a study of a university program.

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Daniel R. Coleman, Chairman
Forum Publication
Advisory Committee

"AID"-ING ACADEMIC PROGRAM EVALUATION
The "Automatic Interaction Detector" As Analysis Tool

Introduction and Perspectives

Academic programs are more than ever called into question. Institutional Research is increasingly asked to provide impartial analyses in these matters, especially when a program is subject to strongly held conflicting views. A case in point is general physics laboratory. Many argue that this resource-consumer is unnecessary, that students can get the same educational benefit via other means. IR can be in an awkward position when asked to "referee." Analytic methods which have served may now be inappropriate or even harmful.

Purpose

Many factors contribute to an educational outcome, perhaps too many to be amenable to traditional methods of statistical analysis. Traditionally one would use a stepwise procedure with regression or discriminate analysis. Unfortunately such analyses assume that the interactions of the explanatory variables are additive and that important interactions are with the variables already included in the model. The "Automatic Interaction Detector," an iterative branching algorithm, (Institute for Social Research, 1973, pp. 553-566) is used in this study as an alternative method which does not require us to make these assumptions. It also provides the researcher with insight as to which of many possible independent variables are best at explaining variance in the dependent variable.

The "Automatic Interaction Detector" (program "AID3" of the "OSIRIS" statistical package) is unique among statistical analysis tools. It is more akin to a chess-playing computer program. At a given point (node) in its analysis, it "looks ahead" to see which possible variable combinations lead to which possible statistical significance. It then chooses the path that maximizes significance. In doing so, it constructs a hierarchical "tree" structure. Nodes at levels nearest the "root" represent the most significance. Variables of the least effect are automatically filtered out to the farthest "branches" of the tree.

The value of AID3 in an educational outcomes analysis is obvious. It can "chew on" the widest possible set of explanatory variables and "spit out" all but the best. With AID3 there is no need to guess at the best set or to use only those variables that are "obviously" appropriate for a good analysis. AID3 automatically provides the best set, which may then be used in more traditional statistical analyses. Others (Cohen, 1983) have used AID3 alone for analyses. The present work used AID3 in combination with more traditional analysis tools, as a "front end" to winnow the possible explanatory variables to a best set of manageable size.

Literature Review

A recent article (Toothacker, 1983) presents the results of several studies related to the objectives of general science laboratory (Dubravcic, 1979;

Kruglak, 1952; Kruglak, 1953; Saunders & Dickenson, 1979) and concludes that they call for the elimination of freshman and sophomore physics laboratories. The literature is not so one-sided, however. Other studies have been inconclusive (Bellanger, 1969; Cunningham, 1946; Power, 1976; Shulman and Tamir, 1973; Watson, 1963). Yet other findings have firmly supported the role of the lecture/laboratory combination (Bradley, 1968, p. 62; Cunningham, 1948). All could be viewed as flawed, with too small experimental populations, too few or too many dependent variables, too little concern for "Hawthorne" effects. (Dubravcic, 1979; Kruglak, 1952; Kruglak, 1953; Saunders & Dickenson, 1979).

Data Sources

At Virginia Tech, it is not necessary that a student take General Physics lecture and laboratory concurrently. As a result, significant numbers do not. Thus one can compare the lecture performance of those students who took the laboratory concurrently and those who did not, from routine university grade reports. This study used five years of such data, covering 2,186 student enrollments, 27 percent of which were for students who did not enroll in the concurrent laboratory. At a gross level, the data were as shown in Table 1 below.

Table 1

Concurrent Laboratory Work and Student Grades in Physics Lecture

Academic Term	Lab Students Num.	Lab Students Grade**	Non-Lab Students Num.	Non-Lab Students Grade	Grade Diff.
Fall 1979	350	2.08	123	1.64	0.44
Fall 1980	347	2.17	138	1.63	0.54
Fall 1981	344	2.59	125	2.07	0.52
Fall 1982	313	2.39	95	2.09	0.30
Fall 1983	245	2.17	106	2.10	0.07
Combined	1,599	2.29	587	1.89	0.40

** Average grade is calculated on the basis that an "A" is 4.00.

At the gross level, it is apparent that students taking laboratory concurrently have historically done better that "non-lab" students. It is also apparent that things began changing in 1982. There is currently little difference in Physics lecture grade between the "lab" and "non-lab" students.

With a large population and with the ability to use unobtrusive measures, conditions were almost ideal for this type of descriptive educational outcomes investigation. With the power of AID3, a broad variety of independent variables could be investigated to answer the question of the probable influence of laboratory on grades in the Physics course. Demographic and academic explanatory variables were drawn from the university data base and added to the grade data. The student variables were the following:

1. Phys. Lect. Grade	2. Concurrent Lab	3. Year enrolled
4. SAT Math Score	5. SAT Verbal Score	6. High School Rank
7. Overall Grade Ave.	8. Student Level	9. Entering Level
10. Student Major	11 Transfer Student	12. Student Sex

Because of AID3's non-additive nature, one may include variables that could hardly be thought grade-affecting. As the above list shows, one may throw in everything, including the kitchen sink. The total population of student enrollees was reduced to 1,997 because some students did not receive "A" through "F" letter grades.

Once the institutional data had been gathered on the Physics enrollees, they were translated into the numeric codes required by AID3. This is an extra step, and it is a minor nuisance. A simple SAS program converted the data from institutional form to numeric as follows:

1. Grd: A 12, B+ 11, B 10, etc	2. Lab: 1 Lab, 0 No-Lab
3. Yr: 79, 80, 81, 82, 83	4. SATM: 0 NA, 1 <500, 2 >500
5. SATV: 0 NA, 1 <500, 2 >500	6. HSR: Class Rank Decile
7. OvGr: 1 NA, 2 0-2, 3 2-3, 4 3-4	8. SLvl: 1 Fr, 2 So, 3 Jr, 4 Sr
9. ELvl: 1 Fr, 2 So, 3 Jr, 4 Sr	10. Majr: 1 Ag, 2 Ar, 3 Bu, 4 Ed, 5 En
11. Xfer: 0 No, 1 Yes	12. Sex: 0 Female, 1 Male

The abbreviations in the above conversion list correspond to the data items investigated (by number). The abbreviations will be used in this paper's data tables and figures.

Method

With AID3 we performed two separate analyses on the data. The first analysis was unconstrained, considering all of the variables to be of the same importance. Under this procedure, the algorithm selects the variable which when used to split the sample gives the largest reduction in the "between" sum of squares. This unconstrained procedure investigates the general question of what variables do the best job of explaining Physics lecture grades.

The second procedure took advantage of AID3's ability to constrain an analysis. Since the immediate question involved the value of concurrent Physics laboratory, the algorithm forced the first division on the "Lab/No-Lab" variable. Further splits were unconstrained.

AID3 analysis yields a hierarchy of explanatory variables. The hierarchy may best be viewed as an "inverted tree," as shown in Figures 1 and 2. The tree diagram for the case where LAB is not forced as the first split is shown in Figure 1. The keys to interpreting the diagram are the node numbers and the hierarchical levels. The lower the node number, the more significant the explanatory variable. The nearer a level is to the root, the more significant are that level's variables. Going down three levels (a good rule of thum ,

Figure 1 shows that the major variables are overall grade average, SAT Math Score, the year the course was taken, and high school rank.

Interestingly, the "Lab/No-Lab" variable does not appear in the diagram, at any level. An unconstrained AID3 presented "sex" as the least significant variable affecting Physics lecture grades. It didn't think very much of concurrent laboratory at all. This sort of result is not generally what the researcher would like to report to a customer who asked about the effect of concurrent laboratory on Physics grades. It also doesn't necessarily show the full picture. As will be seen, the second pass -- with the first split forced on "Lab/No-Lab" -- is valuable, as well as palatable.

Figure 2 is the tree diagram of the analysis with "Lab/No-Lab" the first split. The value of the constrained analysis is obvious. Figure 2 shows that concurrent laboratory is significantly related to the Physics lecture grades earned by the students, worth at least half a letter grade to students of similar academic stature. In addition to concurrent laboratory, it is also obvious that the other major explanatory variables are -- as in the first case -- overall grade average, SAT Math score, the year that the student took the course, and high school rank.

The results of the two runs of AID3 imply three basic conclusions. The first is that the importance of concurrent laboratory depends strongly on when in the analysis it is considered. The second conclusion is that the set of demographic measures which make a difference in explaining grades in the Physics class include overall grade average, SAT Math score, high school rank, and the year in which the student took the course. Finally, some non-additive interactions occur in these data. This observation comes from noting the symmetry of importance of the variables.

From the last observation also comes the conclusion that relatively consistent groupings are important in variables with a large number of categories, such as high school rank. This grouping is important in the strategy of going to an ANOVA (ANalysis Of VAriance). If groupings do not exist then a very large number of cells will result from the interaction terms. Even more unfortunately, the large number of cells with correlated independent variables means that there is a greater likelihood that some of the cells will be vacant.

At this point in the analysis process, AID3 has served its purpose. Following the AID3 analyses, the measures which seemed to be the most relevant in explaining the course grades were used in a factorial ANOVA. This ANOVA, while it obtains significant levels, is computed primarily to determine the relative size of the various main effects and the interactions in explaining course grades. This strategy -- AID3 followed by ANOVA -- was adopted because there were a large number of potential main effects which were seen as being related to the course grade. To include all of these effects and their interactions would have created problems of extremely small and unstable cell sizes. It would have also created the potential for a extremely complex set of "significant" differences that would have been impossible to interpret. Pre-processing with AID3 avoided those problems.

Concluding Remarks

It is always difficult to to prove the outcomes of an educational experience with post hoc data. At the same time it is important that we use the best possible models in descriptive research to infer the probable cause of differences in outcomes. This research makes two contributions in the investigation of factors which influence course performance. First it reports on the specific question of "What is the role of Physics Lab in explaining the performance of students in a Physics course." As noted in the review of the literature, this is currently an issue of concern within the Physics profession.

Of more interest to Institutional Research is the second contribution: demonstration of a method which allows the researcher to consider a large number of variables as possible explainers of course performance without making the restrictive assumptions required by other techniques. In this second area, the discussion of the problems in demonstrating causation and the difficulty in selecting the best model should help those involved in improving our understanding of the factors which influence learning in our colleges and universities.

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Figure 1

AID3 Tree Diagram of Major Effects on Physics Lecture Grade

With Nothing Forced As The First Split

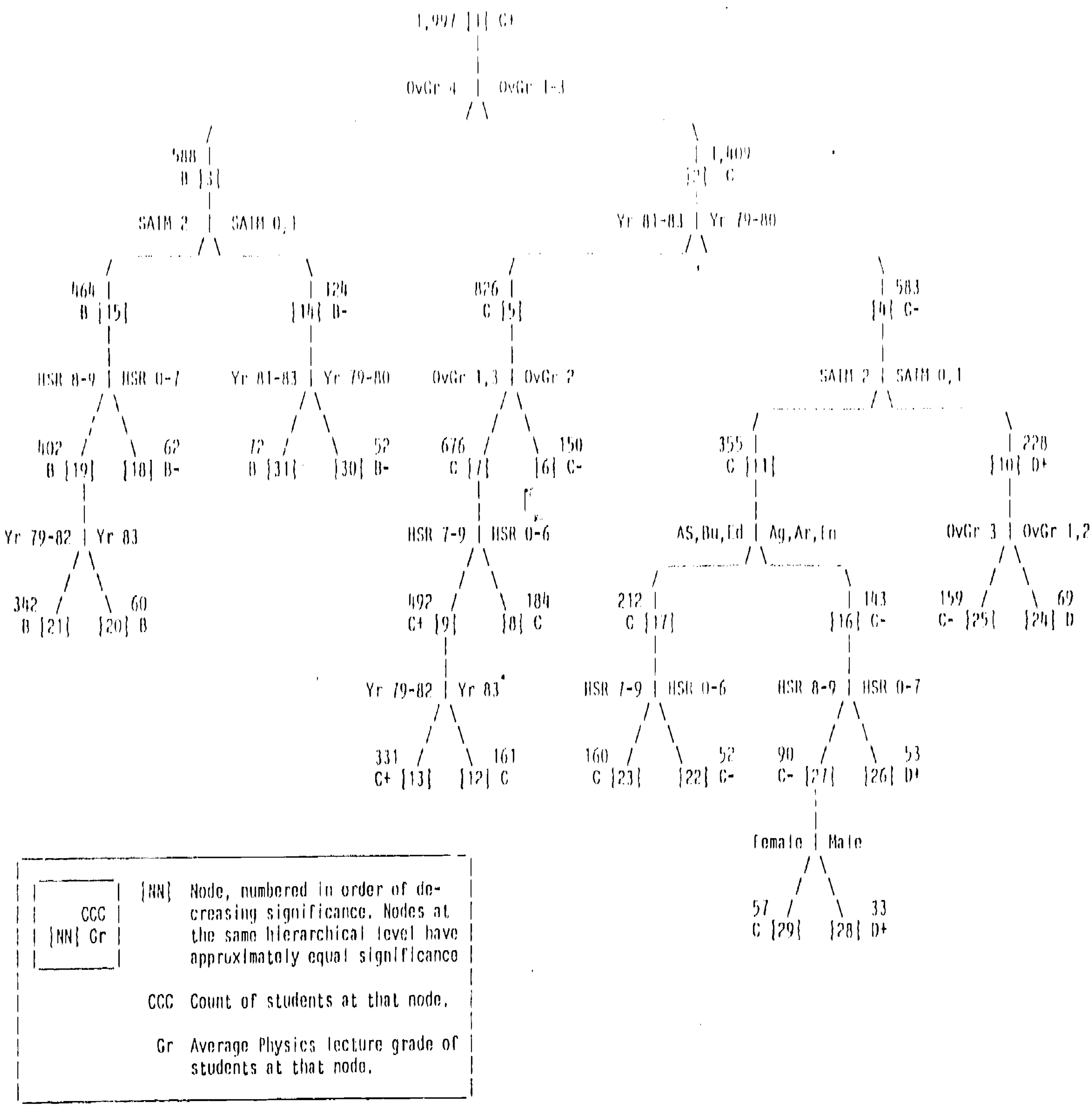

Figure 2

AID3 Tree Diagram of Major Effects on Physics Lecture Grade

With LAB/NOLAB Forced as the First Split