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AUTHOR Costa, Crist H.
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ABSTRACT

The purpose of this study was to combine knowledge of teacher demographic data with time-series forecasting methods to predict teacher turnover. Moving averages and exponential smoothing were used to forecast discrete time series. The study used data collected from the 22 largest school districts in Iowa, designated as FACT schools. Predictions were made for the 1968-69 school year and then validated with the actual data for that school year. Data were organized into 27 types, which were suggested by a literature review. Results of the study show that teachers with less than four years experience showed the highest amount of turnover, with married women under 30 having the highest rate, unmarried females under 30 being second, married males and unmarried males being third and fourth, respectively. (DB)

THE PREDICTION OF TEACHER TURNOVER EMPLOYING TIME SERIES ANALYSIS

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Application of Quantitative Techniques
to School District Decision-Making
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CRIST H. COSTA
Administrator
Department of Educational Systems Development
Milwaukee Public Schools
5225 West Vliet Street
Milwaukee, Wisconsin

Introduction and Statement of the Problem

Education has been described as a profession with high mobility. In March, 1963, the Oregon Education Association (1963) published a research bulletin indicating that of the 18,960 teachers employed during the 1961-62 school year, seventeen percent did not return at the start of the next school year. The state of Nebraska, as reported by Lichtenberger (1958), had a turnover rate for the entire state of thirty-four percent. While circumstances such as marriage, illness, and age make some resignations unavoidable, "Half the young men and women who began teaching in the United States in 1957 expected to leave the profession within five years. Furthermore, only fourteen percent of the beginning women teachers and twenty-eight percent of the beginning men who were queried in a recent nationwide survey planned to make teaching their life work (Folsom, 1958)."

Teacher turnover studies performed in the late 1950's were primarily concerned with the fact that most areas of the country faced a teacher shortage, and replacement of lost teachers would be difficult. Teacher turnover is still of some concern to educators but for different reasons. James A. van Zwoll (1964) views teacher turnover as "a disruption of instruction, an expense of replacement, and a handicap to the effectiveness of the teacher until aware of the community and its resources."

The need for new sources of funding for public schools has become more evident in recent years. Bond issues are becoming more difficult to pass and teacher's salaries seem to be constantly going up. These and other pressures have left school administrators little margin for error in the allocation of physical and financial resources within their district. As Dr. James Mitchell (1969) said at a recent conference in Des Moines:

> Local educational agencies face staggering challenges in the management of their public education financial responsibilities. Difficulties may be summarized: no long range planning; no process for establishing priorities; financial requests unrelated to fiscal taxing power, ..., an absence of problem measurement in terms of costs and benefits; and the lack of financial authority commensurate with responsibility and the consequent lack of accountability.

At present, school districts have no reliable means of projecting faculty turnover. Without some staisfactory estimate of the next year's faculty composition, it is difficult to accurately project future salaries, plan inservice education activities, and make other administrative decisions which heavily depend upon returning staff. This problem of teacher turnover and the need of school administrators to plan for the future combine to form the basis for this study.

Introduction and Statement of the Problem

Initial investigations of the topic were of a much larger scale. At one point, the interest was to build a model capable of simulating staff development within a school district. It was thought that if one could predict turnover with any sense of accuracy, then one might be able to utilize similar methods to predict teacher replacements. If both were possible, an Enrollment projection model could be added to account for staff expansion or reduction, a salary analysis package would be used to predict the changing staff impact upon salaries in the budget and thus eventually have a model capable of simulating the school district activity which accounts for 60%-80% of a school district's budget. An analysis of the magnitude of the original topic led the researcher to conclude that each phase should first be investigated and then decisions about the entire model made at a later time.

Statement of the Problem

Is it possible to predict teacher turnover in a school district utilizing time series analysis techniques and knowledge of teacher demographic data? Since a variety of forecasting techniques were available, the specific questions studied were:

1. Can the type of faculty turnover within a school district be predicted employing moving averages?
2. Can the type of faculty turnover within a school district be predicted employing exponential smoothing?
3. If both techniques are able predictors, is the use of moving averages a better predictor of the type of teacher turnover within a school district than the use of exponential smoothing?

Purpose of the Study

The review of the literature indicated that teacher turnover is not related to school district characteristics such as pupil-teacher ratios and instructional salary expenditures per pupil (Bartholomew, 1969). It is related to characteristics of the teacher. The Orlich and Craven (1968) study of teacher turnover in Idaho concluded by saying, "School administrative staffs must analyze not only the preparation of their colleagues, but also age, sex, and experience if they are to maintain a somewhat stable faculty." The purpose of this study was to combine knowledge of teacher demographic data with time-series forecasting methods to predict teacher turnover. If turnover can be predicted, then the school administrator can use this tool to better plan for the future by keeping the turnover at the level desired within his district.

Definition of Terms

The following terms are defined to make clear the meaning and scope of key words and phrases that are used in this study.

Exponential smoothing. This forecasting technique is called "time series taken out of context". That is, the only input to the forecasting formula is the past history of teacher turnover, not such information as growth in faculty size, or increase in salaries (Winters, 1960). The formula employed in this study is $\widetilde{ET}_t = a*(ET_{t-1})+(1-a)*\widetilde{ET}_{t-1}$, where:

$\widetilde{ET}_t$ = Estimate of turnover at time "t";

a = A "smoothing" or weighting factor;

ET_{t-1} = Actual turnover at time "t-1";

$\widetilde{ET}_{t-1}$ = Estimate of turnover at time "t-1".

FACT Schools. The twenty-two largest school districts in the state of Iowa currently being studied by Project FACT at the University of Iowa.

Sex. The two demographic characteristics of sex and marital status have been combined to form four categories: unmarried female, married female, unmarried male, and married male. It is these four categories that are later referred to as sex.

Teacher Turnover or Mobility. This is the loss of teachers from a school district from one school year to the next. The terms "turnover" and "mobility" are used synonymously in this study.

Teacher Turnover Type. A teacher who has left the school district and can be described by a particular combination of demographic variables: an unmarried male, under 30 years of age and having 4-9 years of prior teaching experience.

Probability. This is the relative frequency of the occurence of an event as measured by the ratio of the number of cases or alternatives favorable to the event to the total number of cases or alternatives. Henceforth, probability will be used interchangeably with the term relative frequency.

Moving Average. A forecasting technique which gives equal weight to as many previous years as desired.

TABLE 1.1

Example of Moving Average Calculations

Year	Percent	Two-Year Moving Total	Two-Year Moving Avg.	Three-Year Moving Total	Three-Year Moving Avg.
1964	88.5				
1965	90.2	[A] 178.7	A_1 89.35		
1966	92.5	[B] 182.7	B_1 91.35	[C] 271.2	C_1 90.40
1967	89.7	182.2	91.10	[D] 272.4	D_1 90.80
1968	90.1	179.8	89.90	272.3	90.77

Note: A - 178.7 is the sum of the percentages for years 1964 and 1965 only.

A_1 - 89.35 is the mean percent for years 1964 and 1965 only.

B - 182.7 is the sum of the percentages for years 1965 and 1966 only.

B_1 - 91.35 is the mean percent for years 1965 and 1966 only.

C - 271.2 is the sum of the percentages for years 1964, 1965, and 1966 only.

C_1 - 90.40 is the mean percent for years 1964, 1965, and 1966.

D - 272.4 is the sum of the percentages for years 1965, 1966, and 1967 only.

D_1 - 90.80 is the mean percent for years 1965, 1966, and 1967.

Possible Forecasting Techniques

There are a variety of mathematical techniques available for predicting teacher turnover. A few of the possible techniques are regression analysis, discriminant analysis, least squares, and time series analysis. The technique chosen for use in this study was time series analysis. Moving averages and exponential smoothing are techniques used to forecast discrete time series. In economic forecasting this means the forecasting of processes such as future sales, product demand, and economic growth. If the process to be forecasted is considered in terms of the turnover of teachers from one period to another, and if the school year is considered as the time period under consideration, then the teacher turnover within the school district can be discussed in terms of a discrete time series. It is a discrete time series in the sense that the concern is for a fixed length of time.

The value of a forecast to an administrator was best stated by Wilson Wright (1947):

> Possibly the most intelligent way to treat a forecast is to regard it as an assumption which it is reasonable to adopt in view of the evidence at hand, and with due awareness of the risks and opportunities to which a business will be exposed from the acceptance point of view.

Norbert Enrich (1969), also commenting on the value of forecasting stated:

> Formal forecasting promotes a more orderly way of doing business in general, based upon definite expectations, plans, and schedules.

Forecasts in this study take one of two different forms: moving averages or exponential smoothing. Ordinarily, when forecasting situations such as sales, the forecaster must concern himself with the possibility of trends and cycles affecting the accuracy of the forecast. The review of literature concerning teacher turnover revealed that teacher mobility is directly related to teacher characteristics of age, sex, and experience on the job. Nothing in the literature suggests that turnover rates should vary greatly from year to year and therefore moving averages should be an adequate technique to account for any long term effect. Carl Dauten and Lloyd Valentine (1968) stated:

> The most widely used measure of the seasonal variation is found by the ratio-to-moving average method. The moving average contains the trend, the cycle, and any irregular factors which may have affected the data.

In discussing the advantages and disadvantages of moving averages, Robert G. Brown (1963) stated:

> The process of computing a moving average is quite simple and straight forward. It is accurate... It is simple for data processing or manual computation. It is, however, difficult to change the rate of response in this system.

Since the size of N (the number of observations combined to form the moving average) determines the stability of the forecasts, the larger the N, the slower the adjustments to new changes in the system. This can be corrected somewhat by keeping N small. A minor disadvantage to using moving averages for predictions is that a great deal of historic data must be stored for later incorporation into the moving average.

The drawback of having to save a great deal of old data is eliminated without any loss in accuracy by employing exponential smoothing. As Winters (1960) stated:

> A prediction made in any period is based upon current data, and all the previous data , but in such a way that only one number (the most recent estimate for the current period) must be retained to be combined with the latest incoming sales information.

Smoothing refers to the fact that each forecast really represents an averaging out of past experience, based upon the weighting of past and actual demands and of forecasts. It is called exponential smoothing because of the fact that with increasing time over successive periods the effect of earlier forecasts diminishes exponentially.

For example: Let t = time;

α = smoothing factor = .2;

D = Demand;

F = Forecast.

$$(1)\quad F_{t+1} = .2D_t + .8F_t$$

$$(2)\quad F_{t+2} = .2D_{t+1} + .8F_{t+1}$$

$$(3)\quad F_{t+3} = .2D_{t+2} + .8F_{t+2}$$

Substituting the equivalent of F_{t+2}:

$$F_{t+3} = .2D_{t+2} + .8(.2D_{t+1} + .8F_{t+1})$$

$$= .2(D_{t+2} + .8D_{t+1}) + (.8)^2\, F_{t+1}$$

Substituting the equivalent of F_{t+1}:

$$F_{t+3} = .2(D_{t+2} + .8D_{t+1}) + (.8)^2(.2D_t + .8F_t)$$

$$= .2(D_{t+2} + .8D_{t+1} + (.8)^2D_t) + (.8)^3F_t$$

Note that by period t+3, the weight given to the first estimate used (F_t) has been reduced exponentially by the power of 3.

In a similar manner to moving averages, the ability to adjust to rapid changes, in the process for which the forecast is being made is also present in exponential smoothing. The smoothing factor is kept small if a gradual change is anticipated, and is made large if a rapid change is anticipated. The size of the smoothing factor determines the amount of weight given to the most recent actual demand. Though, like other forecasting models, exponential smoothing lies one estimate behind the actual shift in the time series, Winters (1960), upon comparing exponential smoothing with two other forecasting models, stated:

> We conclude, then, that the exponential forecasting model has several advantages over more conventional forecasting models:
> (1) It gives better forecasts
> (2) It requires less information and storage space
> (3) It responds more rapidly to sudden shifts in time series so it routinely protects the forecaster.

Limitations of the Study

This study utilized data collected from the twenty-two largest school districts in the state of Iowa designated as FACT schools. Although the conclusions of this study can be statistically generalized to only this population, it can be logically generalized to other school districts having similar characteristics. Teacher information from these schools was edited very carefully by Dr. Bernard Bartholomew, Director of Project FACT, and by his staff, so as to eliminate any errors which might have an effect upon this study. Data from these schools were available only from the 1964-65 school year until the 1969-70 school year. Since this researcher considers four years of data the minimum amount of historic data needed for this model, predictions were made for the 1968-69 school year only and then validated with the actual 1968-69 school year data.

Techniques Used in Data Analysis

A computer program was written in FORTRAN IV level G to capture and pool the data from magnetic tape and produce turnover reports in terms of a three-dimensional set of descriptive characteristics:

1. Sex and marital status were combined to form four categories:
   a. Unmarried females (UF)
   b. Married females (MF)
   c. Unmarried males (UM)
   d. Married males (MM)
2. Age was separated into two or three categories depending upon the sex and marital status of the teacher. Because married women teachers, as reported by the literature cited in Chapter II, leave teaching as a career for a period of time to have and raise families, age was separated into three classifications. Since teachers of other sex-marital status combinations did not show this temporary gap in their career, age was separated into two categories for all other teachers. The categories according to sex and marital status combinations are:
   a. Married Female
      (1) Under 30
      (2) 31-40
      (3) 40 and older

b. Unmarried Female, Unmarried Male, Married Male

(1) Under 30

(2) Over 30

3. Total years of prior experience was separated into three categories:

a. 0-3

b. 4-9

c. 10+

It is best described in terms of Figure 3.1.

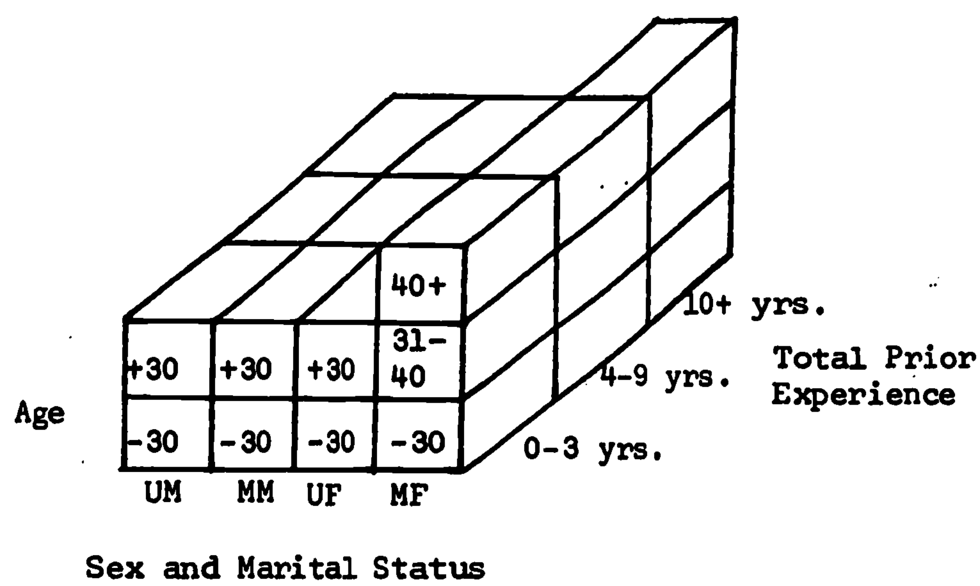

Figure 3.1

Model of Data Organization

The computer program scanned the data, computed, and reported the number and relative frequency of teachers who have worked two successive years in a school district. With data from 1964-65 to 1969-70, the yearly turnover was reported for five years in each of the twenty-two districts. Data in this form was then used to make a point estimate, or an interval estimate, of the turnover rate in 1968-69. Blommers and Lindquist (1960) states:

> Interval estimates are at a disadvantage - in fact, cannot be used - when the estimate is required for use in subsequent calculations. However, in all situations in which single valued estimates are not thus required, interval estimates are to be preferred.

Since the estimate was not needed for further calculations, it was decided to first make a point estimate, but only for the purpose of establishing an interval for the estimating procedure. The size of the interval was chosen after weighing several factors: sample size involved, usefulness of the prediction techniques, and the sampling distribution of the data.

In discussing sampling from a Binomial population, Li (1964) states, "the sample sum or number of successes in a sample follows approximately the normal distribution with mean equal to $n\mu$ and variance equal to $n\mu(1-\mu)$ because $\sigma^2=\mu(1-\mu)$." However, the binomial distribution formed by the sample sum does not follow the normal distribution closely unless the sample is large. Li (1964) also states, "the commonly used working rule is that both $n\mu$ and $n(1-\mu)$ should be greater than or equal to 5 before the normal approximation could be used." The sample size in this experiment was limited to the total faculty count in each sample space which, in this case, was one of the twenty-seven cells of different teacher types, and was frequently less than 10. For a sample the size of 10 to fit Li's rule, the turnover rate would have to be .50. Since the review of literature suggested that this would not always occur, a normal curve approximation was not always possible.

The binomial distribution, being a discrete distribution, requires that the confidence interval be stated in terms of whole values. This being the case, the values obtained as confidence limits would have to be rounded to the nearest whole number and reported as such.

Since the Binomial distribution does not lend itself to the establishment of confidence intervals, it was decided to employ an empirical interval of ten percent. Each point estimate, generated with the aid of the time series analysis techniques, would be used as the estimate with actual turnover expected to lie within plus or minus ten percent of the estimate. For example:

Let $\tilde{E}_t$ = .4518 = the estimate of turnover in time t.

E_t = .5010 = the actual turnover at time t.

If $\tilde{E}_t$ = .4518, then the interval estimate of next years turnover at plus or minus 10 percent from the point estimate is .3518 - .5518. Note in this case, the actual turnover lies within the interval estimate and so this would be considered a successful estimate.

The empirical interval of 10 percent was chosen because it best satisfied the demands imposed:

1. In dealing with the problem of sample size, the width of the interval estimate, in terms of whole people, varies as the sample size varies. When sample size lies between five and fourteen, the ten percent interval is an estimate within plus or minus one person for .1 x 14 = 1.4. As the sample size increases, so does the interval in terms of whole people. If the sample size is 50, the interval width is plus or minus 5 people from the point estimate for .10 x 50 = 5.0.
2. The size of the interval is small enough to allow practical decision making.
3. The use of an empirical estimate does not depend upon the shape of the sampling distribution for its use.

To test the accuracy of the prediction process two different procedures were employed. The first procedure dealt with the question of whether or not the moving average and exponential smoothing technique could predict the type of teacher turnover.

The second procedure dealt with the question of which predictive technique was best. Letting μ_i = the proportion of correct estimates per method i, then:

1. μ_1 equals the proportion of correct estimates using two-year moving averages,
2. μ_2 equals the proportion of correct estimates using the three year moving averages,

3. μ_3 equals the proportion of correct estimates using exponential smoothing with a 0.10 smoothing factor,

4. μ_4 equals the proportion of correct estimates using exponential smoothing with a 0.90 smoothing factor.

The hypothesis tested was $H_0:\mu_1=\mu_2=\mu_3=\mu_4$, using a Chi Square Test of Independence as described by Li (1964). At present there is no reliable means of predicting teacher turnover. If any one of the techniques is best, even if only slightly better than the rest, it would be best to identify it if possible. For this test, 0.10 was chosen as the level of significance, meaning that if H_0 is true, the probability of the observed Chi Square exceeding the tabled value of the Chi Square is equal to 0.10.

Summary of Results

The summary of results of the study are reported according to the listing of the specific questions as stated in the Statement of the Problem.

1. In the overall analysis of the predictions, estimates were made for twenty-five of the twenty-seven types of teachers. Two of the types of teachers, married and unmarried females under thirty years of age with 10 or more years of experience, were empty sets. Of these twenty-five sets of predictions, twenty-one sets had 40 percent or more of its estimates accurate. An accurate estimate of turnover was defined as an estimate that was within 10 percent of the actual turnover. This means that in each of these twenty-one sets, at least 40 percent of the estimates of

teacher turnover were within 10 percent of the actual turnover and were therefore classified as correct estimates. Table 1 gives a complete breakdown on the percent of accuracy achieved. Each case is one teacher type. The percent of accuracy is the percent of correct estimates made for a single type of teacher.

TABLE I

Accuracy Achieved With Moving Averages

Accuracy	Number of Cases Two Year M.A.	Number of Cases Three Year M.A.
Under 40%	4	4
40.0 49.9	4	5
50.0 59.9	7	8
60.0 69.9	4	1
70.0 79.9	2	4
80% or more	2	3

For two year moving averages, less than 40 percent accuracy was achieved when predicting the turnover rate of:

1. married females ages 31-40 with less than 4 years experience;
2. married females over 40 years of age with less than 4 years experience;
3. unmarried males under 30 years of age with less than 4 years experience;
4. married males over 30 years of age with less than 4 years experience.

For three year moving averages, less than 40 percent accuracy was achieved when predicting the turnover rate of:

1. unmarried females over 30 years of age with less than 4 years experience
2. married females over 40 years of age with less than 4 years experience
3. unmarried males under 30 years of age with 4 to 9 years experience
4. married males over 30 years of age with less than 4 years experience.

2. Of the twenty-seven types of teachers, two types were empty sets. These two types were married and unmarried females under 30 years of age with 10 or more years of experience. Of the twenty-five remaining types, exponential smoothing with a 0.10 smoothing factor was accurate in 40 percent or more of the cases for twenty of the types. Exponential smoothing with a 0.90 smoothing factor was accurate in 40 percent or more of the cases for twenty-two of the types. Table 2 gives a more accurate breakdown on the accuracies achieved.

TABLE 2

Accuracy Achieved With Exponential Smoothing

Accuracy	Number of Cases Smoothing Factor = 0.10	Number of Cases Smoothing Factor =0.90
Under 40%	5	3
40.0 49.9	3	7
50.0 59.9	9	4
60.0 69.9	3	5
70.0 79.9	3	2
80% or more	2	4

For exponential smoothing with a 0.10 smoothing factor, less than 40 percent accuracy was achieved when predicting the turnover rate of:

1. unmarried females under 30 years of age with 4 to 9 years experience
2. unmarried females over 30 years of age with 4 to 9 years of experience
3. married females under 30 years of age with 4 to 9 years experience
4. unmarried males under 30 years of age with 4 to 9 years experience
5. married males over 30 years of age with less than 4 years experience.

For exponential smoothing with a 0.90 smoothing factor, less than 40 percent accuracy was achieved when predicting the turnover rate of:

1. married females ages 31-40 with less than 4 years experience
2. married females over 40 years of age with less than 4 years experience
3. married males over 30 years of age with less than 4 years experience.

3. The null hypothesis was retained for twenty-three of the twenty-five types of teachers. For married females under 30 years of age with less than 4 years of experience the null hypothesis was rejected, suggesting that exponential smoothing with a 0.10 smoothing factor was not as good as the other three methods for predicting turnover. For married females over 40 years of age with less than 4 years experience, exponential smoothing with a 0.10 smoothing factor is superior to the other three methods for predicting teacher turnover. When the number of correct estimates were combined over types for all four methods and compared to each other, using a Chi Square Test of Independence, it was decided to retain the null hypothesis $H_0:u_1=\mu_2=\mu_3=\mu_4$. The actual breakdown of accurate responses is reported in Table 3.

TABLE 3

Overall Comparison of Prediction Techniques

	Method			
Estimates	A	B	C	D
Correct	274	274	261	274
Attempted	484	484	484	484
Percent Correct	56.61	56.61	53.92	56.51

Conclusions and Implications

All four predictive techniques appear equally useful in the prediction of teacher turnover. Whether or not the prediction process is accurate enough depends upon the needs of the user of these techniques and computer programs. If fifty percent accuracy is sufficient, then these techniques will serve the user well. No additional analysis was performed to investigate relationships between district characteristics, or teacher types and correct estimates. A quick review of the data in the appendices suggests that more correct estimates were achieved when the sample was large. The minimum size needed to be classified as "large" would have to be determined through further research.

The organization of the data into the twenty-seven types, while somewhat arbitrary in terms of the number of types, was strongly suggested by the literature reviewed. Upon completion of the data collection, it became evident that teacher turnover in this study's population was consistent with the reports from studies performed throughout the country. Teachers with less than 4 years experience showed the highest amount of turnover with married women under 30 having the highest rate, unmarried females under 30 years of age being second, married males, and unmarried males third and fourth respectively.

Computer models now exist where information concerning staff makeup can be put into the model which then reports total salary costs for the existing staff. Perhaps this type of prediction technique, because of its adaptability to computer calculations, can be added to existing models to account for the probable changes in staffing.

If nothing else, the organization of the data in this manner has added additional evidence to support the theory that the rate of teacher turnover does depend upon the type of teacher hired. The comparatively high rate of turnover among teachers with less than four years experience suggests higher initial salaries for beginning teachers is not enough to reduce the teacher turnover and maintain stable staffs. Some other methods, possibly less costly, should be investigated.

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