BASIC FEATURES OF STRUCTURAL EQUATION MODELING AND PATH ANALYSIS WITH ITS PLACE AND IMPORTANCE IN EDUCATIONAL RESEARCH METHODOLOGY

Engin KARADAG

Eskisehir Osmangazi University, TURKEY

Abstract. It has recently been seen that structural equation modeling and especially path analysis have been started to be used frequently in the field of social sciences. However, when educational research is examined, particularly, it can be said that these instruments are not used so much in this field in comparison with the other social sciences fields. Therefore, structural equation modeling and, among its mostly used analysis tests, path analysis are needed to be utilized in educational researches and become widespread. For this purpose, the basic features of structral equation modeling and path analysis with their use and importance in educational sciences have been discussed in this study. Firstly, these two are analysed and their features are outlined. Then the matter why they should be used in the resarch on education has been explained with proper examples.

Keywords: structural equation modeling, path analysis, educational research methodology

Introduction

All over the world educational research play a very important role in formation of educaitonal applications with affecting them. For the last decade it is seen that number of the articles in educational research journals shows a great increase. Some of these studies published on the basis of educational revolutions in a lot of fields. Moreover, most researchers develop theoretical and conceptual framework of the previous research as well as providing qualitative (e.g., content analysis) and quantitative (e.g., meta-analysis) explanations by summarizing key concepts after looking over the literature. By looking the literature over, the researchers approach the outputs, whose reliability often proved, as hypothesis (Onwuegbuzie & Daniel, 2003). Furthermore, although some new analysis processes in educational research field have been used in last ten years, it is seen that the aptitudes (technics applied) frequently used in parameter analysis process are similar (Hsu, 2005). The number of research on structural equation modeling and especially path analysis and books written on this subject are limited in international educational research literature. For this reason, it is a necessary to introduce and generalize structural equation modeling [SEM] and path analysis in the field of education. This study aims to explain basic features of SEM by giving examples for the features of path analysis which is an application of the structural equation modeling and its contributions to the researches on education.

Structural equation modeling

The concept of causation has always become extremely critical issue in social and behavioral sciences. In addition to that the causation concept is usually subjected to empirical patterns in science of behaviour, and in recent years structural equation modeling have been discussed, some point of views are encountered as causality hypothesis can also be tested in non-empirical researches models. SEM, which can be named as a research, was first suggested by Wright (1921). It is a comprehensive technique with regression analysis origin that uses to test the dissertations ojective for the relationship between observed and implicit variables (Pedhazur, 1997; Raykov & Marcoulides, 2000). SEM, besides of being used for similar purposes of multiple regression test, two or more implicit variables depending multi-indicator variable, relative error terms, independent implied variables tested by multi-indicator are used more powerfully in modeling of interactive measure errors (Kline, 1998).

Being completely dependent to therotical part of the study that will be held is the basic feature of SEM. Basicly, the purpose of SEM model is to display whether the pre-determined relation pattern can be proved or not by the obtained data.

The main feature of SEM is its being totally dependent on the theory of the study that is canducted. The purpose of SEM is basically to put forth whether or not the previously decided relation web can be verified by the data obtained. SEM, despite having been developed for use in genetics (Wright, 1921), is a systhematical instrument recently used especially for evaluating the relations among variables and testing theoretical models in the field of psychology, sociology and marketing.

Technically, SEM is used in the prediction of unknown parameters on linear structure equation. The variables in the equations are generally directly observed and implicit variables. In SEM it is presumed that there exists a casuality structure among the implicit variables set and that the implicit variables that can be measured with the observed variables. Implicit variables, one of the most important concepts of SEM, refer to such abtstract notions as intelligence, emotion and attitude, which can only be observed implicitly by means of variables measured through some observable behaviors. There are lots of apparent difficulties in directly measuring the main concept(s) of a study in psychology, sociology or in the other fieldss of social sciences. In psychology self-perception and motivation; in sociology, helplessness and unrest; and in economics, behaviors customer satisfaction and quality perception can be given as examples for implicit variables. These implicit variables cannot be directly measured since they are not observed. Therefore, so in order to operationally define the implicit variable, researchers have to associate the implicit varible with an observable variable. SEM contains one or more linear regession equations that describe how endogenous structures depend upon exogenous structures (Byrne, 1998; Cheng, 2001; Reisinger & Turner, 1999; Sümer, 2000).

SEM is generally composed of a measurement model, which define how implicit variables or theoretical structures rely upon observed variables, and a structural model, which define casual connections and effects among the implicit variables. In SEM, the prediction of parameters is obtained by minimizing relevant function of the difference between S and Σ (θ). S is neutral covariance matrix attained through observed variables, and Σ (θ) is covariance matrix suggested by the model. The function can be generally presented as follows:

$$Q = (s- W(s-\sigma (\theta))' W (s- \sigma (\theta)) \tag{1}$$

s, is a vector that includes variance and covariance of observed variables and the relevant variance, and covariance predicted with the model. W is a weight scale matrix that holds a type of the forms dependent on the presumed distribution for the observed variables. If observed variables have normal distribution with multi variables, the relevant Q function can be shown as follows:

$$Q = 2^{-1} \text{ iz } [(S- \Sigma) W^{a}]^{2} \tag{2}$$

The different selections of W^a generally vary according to the relevant functions used: $W^a = I^{-1}$ shows the ordinary smallest squares; $W^a = S^{-1}$ shows the smallest generalized squares; $W^a = \Sigma\ (\theta)^{-1}$ shows the rescaled smallest squares.

For $W^a = \Sigma\ (\theta)^{-1}$ equation, the function equals to the maximum similarity prediction. A more general statement of this equation includes the minimized mode of the F function.

$$F = \text{In}\ |\Sigma(\theta)| - \text{In}\ |S| + \text{iz}\ [S\Sigma\ (\theta)^{-1}] - (p + q) \qquad (3)$$

The mostly exercised applications in SEM can be divited into two groups: path analysis, and verifying factor analysis. Because of the purpose of this study and the basic features of PATH analysis with its place and importance in educational research, verifying factor analysis has not been mentioned here.

Path analysis

The biggest problem for the social sciences is to know the structure and dynamics of complex systems. Practically all of the social systems such as sociology, psychology and education are composed of multi-interactive components. For researchers, path analysis provides to easily perceive casual links making up the complex systems, to be able to decide under what conditions the variables in causality are one another's cause or effect and to be able to explain this causal connection in mathematical terms has always posed a significant question. The variables in social systems have, in addition to linear relations, functional relations as well. However, all of these functional relations not only difficulty and costly explain but it is also a time-consuming process. Therefore, for the purpose of simplifying the interpretation of complex systems, researchers would prefer explanation of linear relations rather than functional ones. If the system has variables with non-linear relations, then these can be put in a linear form through a transformation process. A transformation process is generally exercised both for endogenous and for exogenous variables (Li, 1975; Scheiner et al., 2000). It is well known that the coefficient showing the degree of relations among the two or more variables on a linear structure is, depending on the situation, called either simple or partial correlation coefficient. Nevertheless, the correlation coefficient showing the variation of two variables together might additionally point out the effect of some other variables. In such cases, researchers, in order to be able to solve the complex causal structure, may wish to put forth the effect of random variables. As can be understood, the casual structure cannot be interpreted merely through an analysis of correlation coefficient. Consequently, the path analysis, a practice of SEM, is applied to explain and readily interpret the systems made up of variables with such perplexing relations. Correlation analysis does not have a distinction of endogenous or exogenous variables, yet causal systems have both exogenous and endogenous variables. Multi-regression analysis is used in the analysis of the linear equations composed through the prediction of endogenous variable with exogenous variables (Allison, 1998). The multi-regression analysis, since mainly utilized to decide whether or not the error variance is less than the total variance of the endogenous variable (Shipley, 2004), require use of many exogenous variables in explanation of variance about the endogenous variable with a high accuracy rate. However, since this will further complicate designing of the model, researchers mostly prefer to decrease the number of exogenous variables that are thought to affect the endogenous variable, yet in this case error margin in predictions would increase. What is more, while multi-regression analysis shows the effect of each exogenous variable on the endogenous variable, it fails to consider effect of another exogenous variable. Therefore, to calculate the total –both direct and indirect– effect of exogenous variable on endogenous variable in a casual system and to analyze more complex models path analysis should again be applied (Streiner, 2005).

The basic purpose in path analysis is to determine to what extent a model designed by means of the relevant literature can be verified through the findings of the study. A simple path analysis is graphically illustrated in Fig. 1.

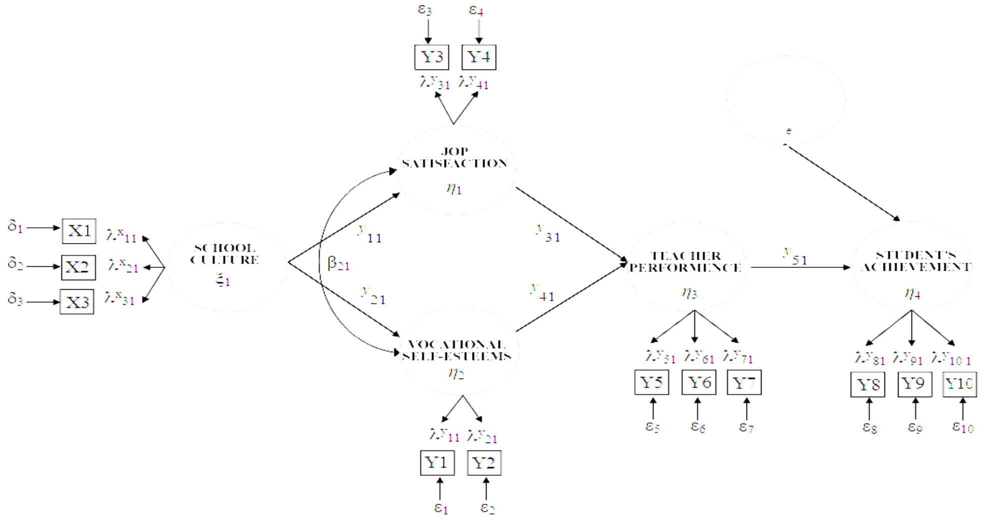

Fig. 1. Scheme of path analysis

According to this model, institutional culture of a school has an influence upon job satisfaction and professional self-respect of teachers. The professional self-respect and job satisfaction has an effect on teacher performance, and the teacher performance on student success. The Fig. 1, besides reflecting a path analysis made with casual variables, it actually studies the relations among variables.

The strengths of path analysis

The correlation coefficients showing the degree of linear relation between two or more variables specify whether the two variables change together or not in addition to determine the extent of change if they do so. Just as this variable may have a cause and an effect, both may be the effect of another cause or causes. For instance, there is a correlation between the heights of twin brohers; this correlation is not due to the fact that one's height affects the other but both are affected by the same cause variables. So, correlation coefficient is doesnot always define the cause – effect relationship. This can be accurately done only with path analysis.

The correlation coefficient between two or more variables consists of the mere effect of variables and their effects with other variables. The path analysis is used for determining the direct or indirect effects of variables.

Taking on the correlation coefficient between two variables, one cannot come to a conclusion as to whether or not there is a common cause affecting these two variables together. If the correlation coefficient between two variables is 0, it would be misleading to conclude that these two variables do not contain a common cause. In most cases, the correlation on negative side is as high as the one on the positive side, and they balance each other. Hence, in such systems, looking into the correlation coefficient, it would be misleading to mention the presence or absence of a common cause in the system. So, path analysis provides researchers to reach most accurate results.

Multiple linear regression models is based upon finding the independent variable of X, which help to account for the change in the dependent variable of Y. It does not reasonably discuss the relations among the variables. Path analysis model outweighs linear regression model in terms of interpreting the causal relations, as well.

While correlation coefficients vary between –1 and +1, path coefficients can exceed these limits. Namely, negative and positive coefficients balance one another and keep the correlation coefficients within these limits.

It is possible to draw different path diagrams among variables with the same correlation and to interpret their linear relations differently.

The researcher, by minimizing the error margin in the prediction of dependent variable, tries to decrease the number of independent variables likely to accede into the model. For this purpose, some statistics criteria have been developed for the selection of independent variables. In this method, all possible combinations of the variables likely to accede into the model are specified. One of the criteria used for deciding which of these combinations are relevant is path coefficients.

The limitations of path analysis

As stated before, path analysis enables one to draw different path diagrams for the same data set and to interpret these accordingly. Yet, there exists an uncertainty as to which one or ones of these different path diagrams can be used or which diagrams are advantageous. There may be difficulties in interpretation of the path coefficient valuses over 1 and, depending on this that of the co-determination coefficients with negative values. On path diagram, if there is a coefficient bigger than 1, this implies the presence of a stabilizing mechanizm (negative effect) in such a system. With this respect, path coefficients over 1 are not meaningful by themselves (Li, 1975).

The path diagram

The path diagram has been developed by Wright for an easy and relevant demonstration of complex causal connections fitting into the assumptions (Land, 1969). The path diagrams, clarifying the possible connections among the variables, are drawn according to the folowing rules: (a) The causal relations presumed to exist among variables in the system are shown with unidirectional arrows drawn from each defined variable to every endogenous variable; (b) The non-causal correlations presumed to exist among exogenous variables in the system are shown with bidirectional curved arrows to separate from causal arrows; (c) The remainnig terms are shown with a unidirectional arrow drawn from the remaining term to the endogenous term; (d) The numbers on the arrows shown in a path diagram are the numerical or symbolical values of the path and correlation coefficients of the presumed causal and correlational connections (cf. Fig. 1).

The symbols in path analysis diagram are explained as follows: ξ: the symbol used for the independent variable; *η*: the symbol used for dependent variables; δ: the error coefficient of observable (Latent) dependent (X, Endogeneous) variables; λ: the coefficient showing the relation between latent and observable variables; ǿ: the coefficient showing the relation among latent independent (X, Endogeneous) variables; γ: The coefficient showing the relation between latent independent (X, Endogeneous) and dependent (Y, Exogeneous) variables; *β*: the coefficient showing the relation among latent dependent (Y, Exogeneous) variables; ε: the error coefficient of observable dependent (Y, Exogeneous) variables.

The path coefficient

The path coefficient from any reason variable to result variable, when the reason variable studied is kept within the observed limits and all the other reason variables are fixed, suggest the variation ratio of the reason variable in standart deviation to variation of all the in-effect result variables in standart deviation. According to this, path coefficient shows the variation extent of any attribute depending on all the other attributes affecting this.

Path coefficient shows the variation extent of any variable depending on all other variables affecting this. There are three structures in the sample of path diagram in Fig. 1: *School Culture, Professional Self-Respect* and *Job Satisfaction*. Let us suppose that we measure school culture with the X1, X2 and X3 items, the professional self-respect with Y1 and Y2 items, and the job satisfaction with Y3 and Y4 items. In this example, school culture is independent variable because it is not affected by any other variables. Professional self-respect and job satisfaction are dependent variables since they are affected by the other variable. The path coefficient equation of this model is as follows:

$$y = \beta y + \Gamma x + \xi \tag{4}$$

$$\eta_1 = y_{11}\xi_1 + \xi_1 \tag{5}$$

$$\eta_2 = y_{21}\xi_1 + \beta_{21}\,\eta_1 + \xi_2 \tag{6}$$

The unknown figures in these two equations are y_{11}, y_{21}, ξ_1, $\xi_{1,}$ ξ_2, β_{21}. The solution of this equation system needs 6 equations.

The standart deviation of professional self-respect variable:

$$V(\eta_1) = E(\eta_1^2) = E[\ (y_{11}\xi_1 + \xi_1)^2] = E[\ (y_{11}\xi_1 + \xi_1)^2] = E[y_{11}^2\xi_1^2 + 2y_{11}\xi_1\xi_1] = y_{11}^2E(\xi_1^2) + E(\xi_1^2) + 2y_{11}E(\xi_1\xi_1) \tag{7}$$

Since error coefficient in the beginning is considered to be 0:

$$= y_{11}^2\acute{\o}_{11} + \varphi_{11} + 0 = y_{11}^2\acute{\o}_{11} + \varphi_{11} \tag{8}$$

The relation between school culture and professional self-respect:

$$Cov(\xi_1\eta_1) = E[y_{11}\xi_1^2 + \xi_1\xi_1] = y_{11}E(\xi_1^2) + E(\xi_1\xi_1) = y_{11}\ \acute{\o}_{11} + 0 = y_{11}\ \acute{\o}_{11} \tag{9}$$

Similarly, if job satisfaction variance is calculated:

$$V(\eta_2) = E(\eta_2^2) = E[\ (y_{21}\xi_1 + \beta_{21}\eta_1 + \xi_2)^2]= \tag{10}$$

$$E[y_{21}^2\xi_2^2 + \beta_{21}^2\eta_1^2 + \xi_2^2 + 2y_{21}\beta_{21}\xi_1\eta_1 + 2y_{21}\xi_1\xi_2 + 2\ \beta_{21}\eta_1\xi_2] =$$

$$y_{21}^2E(\xi_2^2) + \beta_{21}^2E(\eta_1^2) + E(\xi_2^2) + 2y_{21}\beta_{21}E(\xi_1\eta_1) + 2y_{21}E(\xi_1\xi_2) +$$

$$2\beta_{21}E(\eta_1\xi_2)$$

Since error coefficient in the beginning is considered to be 0:

$$= y_{21}ǿ_{11} + \beta_{21}^2V(\eta_1) + \varphi_{22} + 2y_{21}\beta_{21}Cov(\xi_1\eta_1) + 0 + 0 = \tag{11}$$

$$y_{21}ǿ_{11} + \beta_{21}^2V(\eta_1) + \varphi_{22} + 2y_{21}\beta_{21}Cov(\xi_1\eta_1)$$

The relation between professional self-respect and job satisfaction:

$$Cov\ (\eta_1\eta_2) = E[y_{21}\xi_1\eta_1 + \beta_{21}\eta_1^2 + \xi_2\eta_1] = y_{21}E(\xi_1\eta_1) + \beta_{21}E(\eta_1^2) + \tag{12}$$

$$E(\xi_1\eta_1)$$

$$= y_{21}y_{11}ǿ_{11} + \beta_{21}V(\eta_1) + 0$$

$$= y_{21}y_{11}ǿ_{11} + \beta_{21}(y_{11}^2\ ǿ_{11} + ǿ_{11})$$

The relation between school culture and job satisfaction:

$$Cov(\xi_1\eta_2) = E[y_{21}\xi_1^2 + \beta_{21}\xi_1\eta_1 + \xi_1\xi_2] = y_{21}E(\xi_1^2) + \beta_{21}E(\xi_1\eta_1) + E(\xi_1\xi_2) \tag{13}$$

$$=$$

$$y_{21}y_{11}ǿ_{11} + \beta_{21}y_{11}ǿ_{11}$$

The school culture variance:

$$\mathrm{V}(X_1) = ǿ_{11}\text{'dir} \tag{14}$$

When above equations are applied, the path coefficients about our model are obtained. The significance of these coefficients is determined with the help of several adaptation indexes.

An evaluation of relevance of the model

In path analysis, there are different adaptational indexes and their statistical functions used for the evaluation of model relevance. Among the suggested indexes, most commonly used ones are similarity rate chi-square statistics, RMSEA (Root-mean-square error approximation), GFI (Goodness-of-fit index) and AGFI (Adjusted Goodness-of-fit index) (Jöreskog & Sörbom, 2001). The other related measures are PNFI (Parsimony Normed Fit Index), PGFI (Parsomany Goondness of Fit Index), CFI (Comparative Fit Index), IFI (Incremental Fit Index), RFI (Relative Fit Index), NFI (The Normed Fit Index) (Schermelleh-Engel & Moosbrugger, 2003). For the standart adaptational measure values of the indexes, cf. Hair et al. (1998) and Schermelleh-Engel & Moosbrugger (2003).

Relevance of the model and to what extent X and Y variables measure implicit structures can be determined by analyzing multiple correlation coefficients estimated for Y and X variables. These coefficients vary between 0 and 1. If coefficient value is closer to 1, it means that the variable accounts for implicit structures better.

Each structure is evaluated as follows: (i) If *t* values related to each charge for path coefficients are bigger than 2, parameters are statistically meaningful. Moreover, variables are related to statistically determined structures. Thus, variables and structures in the model designed are verified; (ii) The correlation among implicit structures is studied; (iii) Standard errors show how the parameter values are predicted accurately. The smaller the standart error is, the better the predictions are.

Structural equation nodeling and path analysis in educational research

In the twentieth century, methodologists produced many different statistical methods for the analysis of any research data. Throughout the first half of this century, t-test and simple correlation techniques were frequently used in social study and educational research (Edgington, 1974). During the years following 1925, the variance analysis (ANOVA) techniques, developed by Fisher, were often applied especially in many fields of social sciences and by educational researchers (Huberty & Pike, 1999). In the course of time, discussions started over the weaknessess of independent variables needed to make a variance analysis. These discussions sped up with Cohen's study (1968) suggesting a more frequent use of regression analysis instead of variance analysis and the application of the general linear model comprehens also multiple regression analysis. Knapp (1978), stating the canonical correlation analysis as the general linear model, further extended the discussions, and at the present time structural equation models have been developed as alternatives to general linear models (Fan, 1996; Thompson, 2000). However, although pedagogues have articulated a need for more developed statistical analysis techniques in educational studies (Thompson, 1999; Vacha-Haase & Nilsson, 1998), Wilson (1980) and Kieffer et al. (2001), the research findings have puth forth that this is not realistic. Wilson (1980) ascertained that out of the statistical analysis techniques applied in educational studies published between 1969 and 1979, 34% were variance (ANOVA) and covariance (ANCOVA) analysis techniques originally used in agriculture, and 41% were correlation, regression and dicriminant analysis techniques basically exercised in biology. Nevertheless, Kieffer et al. (2001), studied the reports of 756 articles published in *Journal of Counseling Psychology (JCP)* and *American Educational Research Journal (AERJ)* between 1988-1997 and reviewed their statistical analysis methods. They found out that the most common statistical analysis methods used in the studies published in *JCP* were respectively (*i*) correlation analysis, (*ii*) variance analysis (ANOVA), (*iii*) regression analysis, (*iv*) factor analysis and (*v*) discriminant analysis, whereas (*i*) variance analysis (ANOVA) followed by (*ii*) MANOVA/MANCOVA, (*iii*) correlation analysis, (*iv*) regression analysis and (*v*) factor analysis came out to be the mostly used data analysis methods in the researches published in *AERJ*. Although, when compared, two decades exist between these two studies, it is clearly observed that statistical analysis techniques used in educational research have in general not changed.

Structural equation model and path analysis make contribution to determination of how much of total effect of reason(s) upon result(s) in the complex systems composed of variables with causality connections is direct and how much of it is indirect, and to an easy perception and at the same time interpretation of these structures. It is the path analysis, an alternative multivariable technique that enables us to demonstrate the model or models in complex systems by means of path diagrams showing causal connections with arrows and to predict the total amount of direct and indirect effect among the variables. Questions in education are not influenced by single variable, but rather education has complex structures with multiple variables. For instance, in countless studies lots of different relations have been proved that exist between students' attitudes towards a lesson and their school success, yet these studies ignored many variables relating to attitude and success such as length of study time. Since correlation coefficients obtained in this way show only total effect, direct and indirect effects of student attitudes on success can never be determined. This makes it impossible to interpret cause-effect relationships among such complex fields as psychology, sociology and education, but with path analysis one can thoroughly analyze all these in educational research, studying the situations with complex relations.

Another contribution of path analysisis that is enables us to generalize the educational studies. The fundamental resource of causal studies by using linear models is experimental research, but cause-effect relationships in such studies are difficult to generalize. The findings of an educational research are, however, to be generalized since they help to shape/shaping educatinal system of a country. The path analysis paves the way, without any experimental research, for making educational studies and generalizing their findings, which proves it once again to be an obligatory in educational research.

The path analysis further contributes to educational research by helping designing of new models out of theoretical structure of the subject studied. In brief, the path analysis, although it has been recently practiced in many scientific fields like genetics, medicine, biology, agriculture and behavioral sciences since it both leads the educational researcher visually inspect graphs and can predict relative effect of variables in a causal network, is scarcely applied in educational research.

Results

Instead of comparing the structural equation model and path analysis to other multi-dimensional decision making techniques and discussing which is better than the other, this study attempts to bring into light the structural equation model and the path analysis, and their contribution to educational research in brief and simple terms. Depending on the purpose of the research, path analysis is a statistical technique to be used in educational studies. The path analysis and all the other multi-dimensional decision making techniques have their own strenghts and weaknessess. If characteristics of all the statistical analysis methods are studied in depth, the best method serving the purpose of the research should be determined. With respect to their characteristic features, the structural equation model and path analysis are able to bear out different point of views and solutions to statistical analysis techniques used in educational research. These methods enable an educational researcher to study a system not only with the extent of the effect of its dependent and independent variables, but also alternatively with their direct and indirect effects. Therefore, considering all these advantages, the structural equation model and path analysis should extensively be used in educational research methodology.

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✉ Dr. Engin Karadag,
College of Education,
Eskisehir Osmangazi University
Eskisehir, TURKEY
E-Mail: enginkaradag@ogu.edu.tr