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The Application of Exploratory Factor Analysis in Agricultural Education Research

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Factor analysis is not a new method of data analysis. It has been used extensively as a data analytic technique for the better part of the 20th century (Spearman, 1904). Social scientists have used it extensively for examining patterns of interrelationships, data reduction, instrument development, classification and description of data, data transformation, hypothesis testing, exploring relationships in new domains of interest, and mapping construct space (Rummel, 1970). Factor analysis provides a geometrical representation that allows for a visual portrayal of behavioral relationships, a very common research objective in agricultural education.

Factor analysis is a proven analytical technique that has been studied extensively by statisticians, mathematicians, and research methodologists. Rummel (1970) suggested that there have been more methodology goods devoted to the topic of factor analysis than any other social science method or technique. Similarly, more space has been dedicated to factor analysis in the journal Psychometrika than to any other quantitative subject in the behavioral sciences (Nunnally, 1978).

The fact that factor analysis can be so generally applied in the social sciences may help explain the large amount of information that has been published regarding this technique. Yet, despite the copious literature concerning how to utilize factor analysis in social science research, very few evaluations of how factor analysis has been applied in empirical work have been conducted. Ford, MacCallum, and Tait (1986) reviewed and evaluated factor analytic practices in applied psychological research. The study by Ford et al. (1986) is one of the few assessments of the application of factor analysis in the behavioral sciences. Similar evaluations are lacking in other areas of the behavioral sciences and are nonexistent in agricultural education research. Are agricultural educators utilizing this powerful and flexible analytic technique in their studies? If agricultural educators are using factor analysis, are they applying the technique correctly? How should factor analysis be applied in empirical studies and how should it be reported?

When conducting a factor analytic study, a number of issues must be considered. Ford et al. (1986) concentrated on four major issues: the choice of factor model to be used, the decision about the number of factors to retain, the methods of rotation, and the interpretation of the factor solution. Results of a factor analysis and interpretation of the results can be severely influenced by decisions made at each step of a factor analysis (Comrey, 1978; MaCallum, 1983; Weiss, 1976). Weiss (1976) commented that researchers must provide a rationale for each decision, and interpret results in agreement with those decisions.

Factor Model

The researcher must first choose which factor model to employ in the analysis. Factor analysis can be divided into two different approaches: common factor analysis and components analysis (Ford et al., 1986). The component analysis model involves no assumption about unique or error variance in the data. Conversely, the common factor analysis model assumes that the variance in a variable can be divided into common and unique components, with the unique variance being further divided into specific and random error variance (Rummel, 1970).

Common factor analysis and components factor analysis both have supporters and critics. Tucker, Koopman, and Linn (1969) stressed that researchers should give serious thought to the appropriate factor model while designing the study. The components model is more appropriate when the objective is to maximize the ability to explain the variance of observed variables. Common factor analysis is more appropriate when the measured variables are assumed to be a linear function of a set

of latent variables (Ford, et al., 1986; Tucker at al., 1969). Kenny (1979) argued that using components analysis when the objective is to determine relationships among latent variables can lead to inappropriate solutions which do not contribute to substantive theory.

Number of Factors

The number of factors that are retained prior to rotation have considerable influence on the outcome of a factor analysis (Ford et al., 1986). As with choosing a factor model, the researcher has a decision to make regarding the criterion to be used for retention of factors. Unfortunately, various criterion rules used by researches often lead to different solutions (Ford et al., 1986; Humphreys & Ilgen, 1969; Humphreys & Montanelli, 1974).

The Kaiser criterion of retaining factors with eigenvalues greater than one is often cited as the most appropriate for components analysis (Kim & Mueller, 1978; Weiss, 1976). Tucker et al. (1969) found in a study utilizing a known factor structure that the Kaiser criterion often incorrectly estimated the number of factors. The scree test and parallel analysis have the most support among alternative criteria (Ford et al., 1986). A recommended strategy is to use a number of decision rules and to examine a number of solutions prior to coming to a final conclusion on the number of factors to retain (Ford et al., 1986; Comrey, 1978; Harris 1967).

Rotation

The rotation of factors is done in order to improve the meaningfulness, reliability, and reproducibility of factors (Ford et al., 1986; Weiss, 1976). The prime objective of rotation is to achieve simple structure (Thurstone, 1947). Simple structure is achieved by rotating factors around the origin until each factor is maximally colinear with a distinct cluster of vectors (Rummel, 1970). Oblique rotation allows factors to be correlated, while orthogonal rotation generates factors that are statistically uncorrelated (Ford et al., 1986). Nunnally (1978) cited the simplicity, conceptual clarity, and ease of subsequent analysis as strengths of orthogonal rotation. Oblique rotation adds statistical complexity requiring greater user sophistication and care in interpretation (Ford et al., 1986). The added complexity of oblique rotation provides additional information in the form of factor intercorrelation. Harman (1976) argued it is because of these factor intercorrelations that oblique rotation more accurately portrays the complexity of the variables of interest as factors in the real world are rarely uncorrelated.

Interpretation

The ultimate goal in factor analysis is the identification of the underlying constructs (Ford et al., 1986). Interpretation is the process in which the researcher labels or gives meaning to the results of the factor analysis. Rules have been established to guide interpretation and reduce subjectivity. A commonly used rule specifies that only variables with loadings of .40 or higher on a factor should be considered (Ford et al., 1986). Ford et al. (1986) and Rummel (1970) argued that interpretation calls for an examination of high and low loadings, as well as sign across variables.

There are other issues besides the major issues discussed above which impact the quality of a factor analytic study. Large sample sizes are highly desirable in factor analysis (Browne, 1968). Recommendations vary from five observations per variable to a ration of 10:1 (Nunnally, 1978). These ratios are hard to obtain in some agricultural education research because of small sample sizes. Ford et al. (1986) considered computer program package and reporting of factor analytic results as important issues affecting a factor analytic study. Rummel (1970) specified that published studies should contain the necessary information to allow for critical evaluation of the research, replication, and advancement of knowledge. Ford et al. (1986) argued that published results should include the factor model, method of estimating communalities (if applicable), method of factor retention, rotation method, strategy of interpreting factors, eigen values of all factors, percentage of variance accounted for, complete factor loading matrix, correlation matrix and descriptive statistics, computer program package, and pattern matrix and interfactor correlations (when oblique rotation is used).

Purpose and Objectives

The use of factor analysis and researchers application of the technique have rarely been studied. In addition to the study by Ford et al. (1986), there was a study by Glass and Taylor (1966) that examined the use of factor analysis in education. There has not been a study that

evaluated the use of factor analysis in agricultural education. The purpose of this study was to assess and evaluate current factor analysis practices in agricultural education research. The following research questions were used to guide this study:

> To what extent have agricultural education researchers used factor analysis during the past five years?
>
> What decisions were made by agricultural education researchers relevant to the factor model, number of factors, rotation, and interpretation?
>
> What results did agricultural education researchers present in published factor analytical studies?

Procedures

Two major refereed research publications in agricultural education, the Journal of Agricultural Education (JAE) and The Proceedings of the National Agricultural Education Research Meeting (NAERM) were examined for studies that used factor analysis as an exploratory analytical technique. Based on the methodology utilized by Ford et al. (1986), every article in the two publications was reviewed for a five-year period from 1988 to 1992 inclusive.

Studies that utilized factor analysis were coded according to factor model, factor retention, rotational method, and interpretation. Factor analysis studies were also coded for sample/variable ratio, statistical computer package, and presentation of the correlation matrix, communality estimates, eigenvalues, factor loadings, and percentage of variance accounted for by the factors.

Results

Use of Factor Analysis

A total of 402 articles were reviewed from Volumes 29 through 33 of JAE (N=176) and from Volumes 15 through 19 of NAERM (N=226) (Table 1). Of the 402 articles reviewed, 22 (5.5%) utilized factor analysis. There were 13 articles in NAERM and 9 articles in JAE which used factor analysis as a data analytic technique.

Factor Analysis Decisions:

Due to researchers' lack of reporting, it was not possible to determine which factor model was used in half (N=11) of the studies using factor analysis (Table 2). The components model was the most popular one chosen (N= 7, 32%) in the articles where it was possible to determine the model. Just four (18%) articles stated that the common factor model was used.

A majority of articles (N=14, 64%) also failed to provide enough information to determine the decision rule for the number of factors to be retained. Of the decision rules reported, the scree test (N=4, 18%) and some combination of tests (N=4, 18%) were the most popular.

Nearly half (N=10, 45%) of the articles did not report which rotational method was used. Orthogonal rotation was the rotation of choice (N=8, 36%) of the articles that did report rotational method. The majority of articles (N=15, 68%) did not present any rotated factor loadings.

Half of the articles (N=11) that used factor analysis did not present enough information to determine how the factor solution was interpreted and factors labeled. Nearly half of the articles (N=10, 45%) used a minimum value based on factor loading size as their strategy in interpreting factors.

Published Results:

The majority of articles (N=14, 64%) did not report the sample-to-variable ratio. Nearly half of the studies (N=10, 46%) presented the statistical package used with the majority citing SPSS (N=9, 41%). Only two studies (9%) presented the correlation matrix used as input for the factor analysis. Only one study (4%) reported communalities. Just four studies (18%) reported eigenvalues. Nearly half of the studies (N=10, 45%) did report the variance accounted for by the retained factors. Just four studies (18%) reported interfactor correlations.

Conclusions

Despite factor analysis being a well-known, frequently used statistical technique in the social sciences and applicable for agricultural education, agricultural educators rarely use this analysis. During the past five years, just over five percent of

Table 1. Studies Published in the Journal of Agricultural Education (v. 29-33) and the Proceedings of the National Agricultural Education Research Meeting (v. 15-19) that Utilized Factor Analysis (n=402)

Data Analysis	Journal of Ag Ed f	Journal of Ag Ed %	NAERM Proceedings f	NAERM Proceedings %	All Studies f	All Studies %
Included Factor Analysis	9	5.1	13	5.8	22	5.5
Did not include Factor Analysis	167	94.9	213	94.2	380	94.5
Total	176	100.0	226	100.0	402	100.0

Table 2. Summary of Decisions in the Application of Factor Analysis of Studies Published in the Journal of Agricultural Education (v. 29-33) and the Proceedings of the National Agricultural Education Research Meeting (v. 15-19)

Decision	Journal of AgEd f	Journal of AgEd %	NAERM Proceedings f	NAERM Proceedings %	All Studies f	All Studies %
Factor Model						
Common	1	11.1	3	23.1	4	18.2
Components	5	55.6	2	15.4	7	31.8
Not present	3	33.3	8	61.5	11	50.0
Number of Factors						
Eigenvalue>1.0	0	0.0	0	0.0	0	0.0
A priori	0	0.0	0	0.0	0	0.0
Best fit	0	0.0	0	0.0	0	0.0
Scree test	1	11.1	3	23.1	4	18.2
Combination	3	33.3	1	7.7	4	18.2
Not presented	5	55.6	9	69.2	14	63.6
Rotation						
Orthogonal	6	66.7	2	15.4	8	36.4
Oblique	1	11.1	3	23.1	4	18.2
Not presented	2	22.2	8	61.5	10	45.4
Interpretation						
Minimum value	4	44.4	6	46.2	10	45.4
High loadings	0	0.0	0	0.0	0	0.0
A priori	0	0.0	0	0.0	0	0.0
Other	1	11.2	0	0.0	1	4.6
Not presented	4	44.4	7	53.8	11	50.0

the studies in the two major research publications of agricultural education utilized factor analysis. Why aren't agricultural educators using this common, yet powerful analysis more often? One possible explanation is that many studies in agricultural education lack a sample size large enough to conduct a factor analysis. A study with 30 variables would require at least 150 subjects in order to conduct an adequate factor analysis. Perhaps another reason why agricultural educators do not utilize factor analysis more frequently is because of their lack of understanding of this analytic technique. Rummel (1970) argued that a communications gulf already exists between researchers who apply or understand factor analysis and those who do not.

Results of this review indicate that many agricultural educators lack a clear understanding of factor analysis as the technique is often poorly applied in agricultural education. A major concern is the lack of reporting concerning crucial decision

issues in conducting a factor analysis. When decisions were reported, they were often inappropriate. The components model was the most cited choice of factor model. Since most of the studies were interested in relationships among unmeasured latent variables, there seems to be an overdependence on the components model. Similarly, when choosing a rotational method, a majority of researchers chose an orthogonal rotation to force independence among the factors without theoretical justification. Ford et al. (1986) suggested that since orthogonal rotation is a subset of oblique rotation, it makes more sense to do an oblique rotation and check to see if the factors are interdependent or dependent of each other. The use of an orthogonal rotation when the factors are interdependent will affect the conclusions drawn from the data (Dunham, 1976; Ford et al., 1986). Finally, the use of a minimum score is arbitrary and can result in a loading of .40 being considered significant and a loading of .39 being ignored in defining a factor. Reliance on a singular strategy, such as minimum loadings, results in a reduction of information used for defining a factor (Ford et al., 1986).

Reporting practices of factor analytic studies are an area where many agricultural educators, both authors and reviewers, need to improve. A majority of studies using factor analysis failed to report the major decision issues in conducting a factor analysis. Additionally, when factor analytic procedures were stated they were often presented in a confusing manner. Only one study presented the information necessary for an informed review and replication of results. The presentation of factor analytic results such as a correlation matrix, eigenvalues, or communality estimates were almost always lacking. Lack of such results makes it impossible for reviewers to determine the appropriateness of using factor analysis. However, these articles were still accepted by the reviewers for publication.

Recommendations

Many agricultural educators need to increase their understanding of factor analysis if it is to be used correctly. The basics of factor analysis should be taught in agricultural education graduate programs so new faculty feel comfortable using this technique. Additionally, factor analysis workshops should be taught at regional and national meetings so that current faculty who are unfamiliar with factor analysis can gain a basic understanding of the technique.

Agricultural educators who currently use factor analysis need to follow recommendations found in the literature regarding technique and presentation of factor analysis results. Reviewers of agricultural education studies should be sure that the researcher describes the factor analysis methodology adequately with accurate terminology. Researchers and reviewers should make sure that the factor model is related to the research objectives. Oblique rotation should be used unless a theoretical case is made for an orthogonal rotation. Multiple solutions should be examined prior to the decision on factor retention, and the resulting factors should be interpreted based on the knowledge of the variables and an examination of all factor loadings.

Researchers, reviewers, and editors of agricultural education research publication should also be sure that studies using factor analysis present the procedures clearly and in enough detail for informed review, replication, and cumulation of knowledge. Given the limitations of space in agricultural education research publications, not every piece of information concerning a factor analysis can be presented. Every researcher using factor analysis should at the minimum report the decisions made regarding the major issues in conducting a factor analysis. A better understanding of factor analysis among agricultural educators and better methodology when using factor analysis will improve agricultural education research.

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