Structure Of Latent Factors In The Learning Of Statistics

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ABSTRACT

Today, almost all curricula in the social sciences contain at least one course in statistics, given its importance as an analytical tool. This work identifies the latent factors relating to students' motivation and attitudes toward statistics and tests their covariance structure. Specifically using a structural equations model, the work confirms that the evaluative factors affect the affective factors and the interest variable affects the level of anxiety. The findings obtained using the partial least squares method allow the authors to confirm the proposed relations and validate the model.

Keywords: Statistics, latent factors, structural equations, anxiety.

1. INTRODUCTION

Today, almost all curricula in the social sciences contain at least one course in statistics. This reflects the increasingly widespread idea that students need to have at least some understanding of statistics to be able to understand today's world. The importance of this subject has encouraged researchers to reflect on the objectives of the quantitative disciplines, both in the short term (successfully passing the course) and in the long term (knowledge and skills gained for future professional activity) and about the contents (subject, weight of mathematical or probability formulae, exploratory analysis of data, etc.). It is also necessary to analyse the question of the students' motivation and attitude towards courses with statistical content, which are typically seen as "difficult". The current work focuses on this question.

As Phillips (1980) pointed out, students' attitudes toward statistics can either be an important obstacle to learning the subject or a significant advantage. Studies such as Roberts and Saxe (1982), Beins (1985), Wise (1985) and Katz and Tomezik (1988) show the relation between students' attitudes toward statistics and their academic results or future professional use of this tool. In Spain, Auzmendi (1992), Sánchez-López (1996), Gil (1999), Bayot et al. (2005) and Mondéjar, Vargas y Bayot (2008) confirm the correlation between students' attitudes and their performance in statistics.

The main objective of this work is to analyse the origin of the problems detected in the learning of disciplines with a high quantitative content. For this purpose, the authors measure students' attitudes toward statistics.

This work uses Bayot et al's (2005) questionnaire about attitudes toward statistics, which decomposes attitude into two subscales - one affective and the other evaluative - both bi-dimensional in structure. With regard to the affective subscale, one factor measures the degree of interest in the subject and the other the level of anxiety and nervousness of the students when studying the subject or tackling statistics problems. The evaluative subscale also consists of two components, one measuring the utility students perceive for their current studies and the other measuring the utility for their future professional career.

2. PROPOSAL AND METHODOLOGY

From the latent structure obtained in the literature with this questionnaire, the most important variables are those of the affective component – the domain in which researchers have shown most interest. Specifically, and in

an extensive specialist bibliography around the subject of anxiety, many works study the anxiety or nervousness construct in education and its relation with academic performance (Pelechano, 1975; Hembree, 1988; King, Ollendick and Gullone, 1991; Seipp, 1991; Birembaum and Nasser, 1994; Hardy and Hagtvet, 1996; Pere, Varca and Lorenzo, 1999). Attempting to influence the students' level of anxiety can improve their academic performance, so it is important to analyse the effect that the rest of the latent variables have on the level of anxiety. Moreover, to quantify the indirect effects, it is also useful to analyse the effect of the evaluative variables on the level of interest and the relation between the perceived utility factors. Consequently, the current work aims to test three basic hypotheses about the relations between the latent factors:

Hypothesis 1: The evaluative factors (utility in professional career, and utility in studies) affect the affective variables positively in the case of interest and negatively in the case of anxiety.

Hypothesis 2: The level of interest in the subject has a negative effect on the level of anxiety.

Hypothesis 3: The perception of the professional utility of statistics has a positive effect on the perception of the utility in the studies.

To confirm these hypotheses, the authors estimate a structural model using partial least squares (PLS), since this method does not require the initial assumption of normality of the variables, there is no solidly established theory, and the research model aims to predict the effects of some variables on others, as Anderson and Gerbing (1988), Barclay et al. (1995) and Chin et al. (2003) recommend.

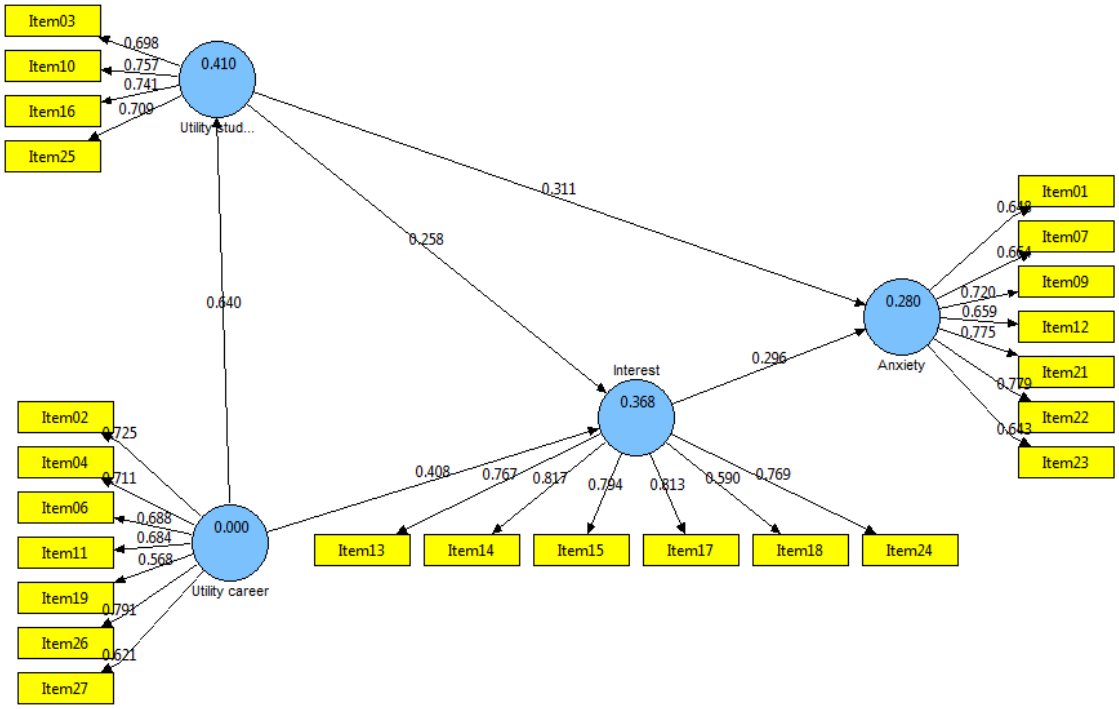
3. RESULTS

The empirical study uses a sample of 374 students from the University of Castilla-La Mancha (Spain) enrolled on a unit with statistical content for the first time during their university studies. The study has an ex-post-facto design and took place in the second week of classes in order to ensure that the results were not biased by factors, such as the progress of the unit, the performance of the teacher, or the partial results obtained.

The first step was a factor analysis of the complete set of 27 items and of the four factors, two corresponding to the affective and two to the evaluative component. The first factor is related to the students' interest in statistics, which reflects a positive attitude towards the subject. The second factor measures their nervousness, or anxiety, about using statistics. Both these factors consist of items from the affective component, and reflect its duality. The other two factors consist of items from the evaluative component. The third factor measures the value students attribute to statistics for their current studies. Finally, the fourth factor measures the students' perception of the utility of the subject for their future professional or research careers. The evaluative component is also dual, since the students assess both the present and future value of statistics for them personally (in their current studies and in their future careers, respectively). Finally the authors carried out a factor analysis for each of the two components studied. Both show a bi-factor structure that coincides exactly with that obtained in the global factor analysis, the items grouping into the same factors. The factor structure obtained is coherent with the results of earlier work in the specialist literature and captures both the affective and evaluative dimensions, both centring on two basic dimensions.

Bayot et al. (2005) and Mondéjar, Vargas and Bayot (2008) confirm that the statistical and psychometric properties of their questionnaire are satisfactory in their original work, but researchers have not studied the relation between the factors obtained in depth. Thus, in the current work, the authors carry out a confirmatory factor analysis. This involves the estimation of a structural equation model to determine the structure of the covariance matrix. For the measurement submodel, the authors use the factor structure from the first step, which allows them to decide which items are used as indicators of each latent variable (factor), as Figure 1 shows. For the structural submodel and following the theoretical framework outlined in the previous section, the authors consider the professional utility variable as exogenous, since it can affect the perceived utility of the subject in the students' current studies. Both the perceived utility variables affect, in turn, the level of interest in the subject. Finally, the model includes the relations between these three variables and the anxiety variable. This latter variable has an inverse scale, so the relations are always positive (Figure 1).

Figure 1: Estimation of structural equation model



The estimation process is through the partial least squares (PLS) technique and uses the software SmartPLS 2.0.M3 (www.smartpls.de). The results obtained for the measurement submodel validate the choice of indicators made, except for items 5 and 20, the loadings of which are too low, so they are eliminated following Bagozzi and Yi's (1988) criterion. This result also constitutes a measure of the validity of the questionnaire used to capture the four latent dimensions.

With regard to the reliability of the measurement instrument, the Cronbach alpha exceeds the standard criterion of 0.7 for all the latent variables (Nunnally and Berstein, 1994), as Table 1 shows. At the same time, the composite reliability exceeds 0.8 in all cases.

Table 1: Reliability Measures

	AVE	Composite Reliability	R^2	Cronbach Alpha	Communality	Redundancy
Anxiety	0.4906	0.8701	0.28	0.8266	0.4906	0.0886
Interest	0.5809	0.8916	0.3676	0.8527	0.5809	0.1162
Utility studies	0.5277	0.817	0.4098	0.7014	0.5277	0.2161
Utility career	0.4724	0.8613	0	0.8113	0.4724	0

With regard to the convergent validity (AVE), the values of the four constructs approach or exceed 0.5, as Fornell and Larcker (1981) recommend. With regard to the structural submodel, Table 1 shows the R^2 coefficients of the regressions of the latent variables. These are significant and exceed 0.1 in all cases except for utility in the career (Falk and Miller, 1992). Table 2 shows the analysis of the direct and global effects. Clearly, a dependence relation exists between the latent variables, which tends to confirm the starting hypotheses for the model.

Table 2: Direct and Global Effects Between Latent Variables

Direct effects				Global effects			
	Anxiety	**Interest**	**Utility studies**		**Anxiety**	**Interest**	**Utility studies**
Interest	0.2963			**Interest**	0.2963		
Utility studies	0.3108	0.2577		**Utility studies**	0.3872	0.2577	
Utility career	0	0.408	0.6402	**Utility career**	0.3688	0.573	0.6402

4. CONCLUSIONS

This work has tested the covariance structure of the affective and evaluative factors that influence students' attitude towards statistics. The authors use Bayot et al.'s (2005) questionnaire to quantify this attitude. The authors believe that this questionnaire is more suited to the group studied here and that it has the advantage that both subscales can be decomposed jointly.

The first conclusion is that the estimation of the measurement submodel supports the validity of the questionnaire used to operationalise the latent factors, since almost all the items are relevant (24 out of 27) and all items load on the right construct. In the structural submodel, the estimations are consistent with the three starting hypotheses.

With regard to the first hypothesis, the regressions to explain the affective variables are significant, with coefficients of determination of 0.368 for interest and 0.280 for anxiety, which are satisfactory according to the accepted criteria in the specialist literature. With regard to the relations, the effect of the utility factors on interest (0.258 for utility in studies, and 0.408 for utility in career) are significant, confirming the hypothesis that a greater perceived utility of statistics leads to an increased interest in the subject. For the relation between the evaluative variables and anxiety, the direct effect of utility in the studies has a coefficient of 0.311, while the direct effect of professional utility is not significant, although the indirect effect is, as Table 2 shows. This supports the first hypothesis that a greater perceived utility also reduces the students' level of anxiety with respect to this subject.

For the second hypothesis, the coefficient of regression of interest on anxiety is high (0.296), which confirms the initial assumption that a greater interest in statistics significantly reduces the students' anxiety-nervousness with respect to the subject. Finally, the results also confirm Hypothesis 3 since perceived professional utility has a strong effect on utility in the studies (0.640).

Globally, the results confirm a model that can offer guidance about how educators can reduce students' level of anxiety with respect to statistics. Specifically, if educators can familiarise their students about the social applications of statistics, this should reinforce their perception of the utility of this discipline for their current studies and increase their interest in studying the subject. These effects should indirectly translate into a reduction in the students' level of anxiety. Likewise, efforts to directly boost students' interest in statistics or their perception of its utility in their current studies should also reduce their level of anxiety.

Efforts to reduce the level of anxiety-nervousness should lead to improved academic performance in statistics among students, so this model could help educators design strategies to do this, or provide a means of evaluating the effectiveness of such strategies.

Hypothesis testing in statistics is such that this work cannot be considered conclusive. Both its findings and its theoretical contribution should encourage future work to test this model using structural methods such as maximum likelihood or generalised least squares, as well as to test more detailed models. Another possibility for future research would be to analyse the effect of a virtual learning approach on these factors and their covariances, in the line of Suanpang, Petocz and Kalceff (2003) or Mondéjar, Vargas and Mondéjar (2007), or to include other

explanatory factors. Finally, researchers should also use other tests to measure students' level of anxiety to see whether the results remain unchanged.

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