

# Empirical Study on Students and their Attitudes toward Statistics Course and Statistical Field

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**Abstract** The aim of this study was to verify whether there are significant differences between the profiles of the mean score students from a sample of three universities, regarding attitude toward the statistics' course and attitude toward the statistical field. The universities were: Universidad Cristóbal Colón (UCC), Universidad Politécnica de Aguascalientes (UPA) and Universidad Autónoma de San Luis Potosí (UASLP). The *Attitudes toward Statistics (ATS)* scale -proposed by Wise in 1985- was utilized for this purpose. The survey was conducted among 672 students enrolled in mathematics courses, and data were processed through discriminant analysis. The results suggest that the ATS of students at UPA are distinct from the attitude observed on students at UCC, and the ATS of students at UASLP are different from students at UCC and UPA.

**Keywords:** *Attitudes toward statistics (ATS), Attitudes toward field (ATF), Attitudes toward course (ATC), Canonical discriminant functions, Criterion of proportional randomness (CPROP) and the Maximum randomness criterion (Cmax)*

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## 1. Introduction

Some studies have reported results about Attitudes toward Statistics (ATS). Estrada et al. [1] suggest that in general, the ATS of future teachers are favorable. The highest contributing factor is the cognitive ability, and the most influencing factors to learn the subject, are ability and skills. Regarding it, Mondéjar et al. [2] applied a new test to measure students' ATS with four dimensions: interest, anxiety, usefulness perceived about the career and usefulness of statistics for their professional future. Results show that the way students study affects ATS. When a student takes a deeper approach to his study, he tends to consider the subject more attractive, conceive it more useful for their career, and show less anxiety about the matter. However, when a student studies in a superficial way, previous ATS are more problematic because the student has a lower level of interest, a slight increase in anxiety, and a weak conception of the subject [3,4,5].

Auzmendi [6], through multiple-regression analysis identified significant predictors of attitudes: student expectations of success or failure, the willingness of the student to computers, previous training, motivation, and anxiety. Gil [7] identified five factors related to ATS: anxiety, interest, confidence, utility and value. Furthermore, it points out that if students know the

usefulness of the subject and its relationship to the field of study, it provides a favorable attitude. However, weak interest and anxiety of learners cause an unfavorable attitude. Pierce [8] applied a pre-test and post-test to 36 students. In the pre-test, students of all courses were sure that they could learn, even if the course was challenging, nevertheless, they perceived that interest and affection were not essential to have a better attitude toward the subject.

In another study, Vanhoof et al. [9] examined the relationship between ATS and test results in the short and long terms. The attitude was assessed by the ATS test of Wise [10] which includes two sub-scales: Attitudes toward Course (ATC) and Attitudes toward Field (ATF). The results show that in the early years (short), students' attitudes were more favorable to the course than to the field of study.

Baloğlu et al. [11] researched on the relationship between attitudes (toward the current course and toward the field of study) and anxiety toward statistics, the value of statistics, anxiety toward the class and evaluating, the idea of a computer, fear of asking for help, and fear of teachers. Results show that there are negative ATS, generating anxiety in the elderly and students, even in courses or in its application.

Therefore, the following questions arise: What is the student's ATC? What is the student's ATF?

## 2. Literature Review

Recently García-Santillán et al. [12] noted that almost in every study (degree and post-degree), statistics courses were present in the curricula of the university academic programs. Within educational research, students' scholarly performance in statistics has justified the need to observe the students' attitude, mainly because it has a significant influence on the process of teaching and learning. Furthermore, an important argument concerning students' ATS is that, as an essential component of their background, after their college preparation they may carry out academic and professional activities [6,13,14,15].

In another research, Mondéjar et al. [2] developed a test upon the methodological principles of ATS [10], and Attitude Scale toward Statistics (EAE) [16]. Their main objectives were to develop a test on students' ATS and to analyze the influence over the way they study. Mondéjar et al. [2] characterize the psychometric properties of this new scale to measure the ATS; they obtained an effective tool to measure or quantify students' affective factors. The result may show that the level of nervousness-anxiety, the university course studied, and other factors such as gender, affect the studying process. As said in [17], student's attitudes can suppose an obstacle or be an advantage for his learning.

Other studies [9,10,18,19,20,21] showed a relationship between the ATS and academic outcomes or the professional use of statistics. They have confirmed the existence of a definite correlation between students' attitudes and their performance in this area. Other studies, conducted in Spain, [7,16,22] also have validated a positive correlation between students' attitudes and their performance at statistics.

García-Santillán et al. [23] noted that among the first operative definition and measure of ATS is the test named Statistics Attitudes Survey (SAS) of Roberts and Bilderback [24], which focuses on the statistical field.

Other seminal works relating ATS are the ATS scale of Wise [10] and the scale of Auzmendi [16], both to collect the most relevant characteristics of the students in regard to their attitude toward statistics, and their difficulties with the mathematical component and prejudice to the subject. From them, some other works have been derived [25,26].

The ATS scale consists of 29 items grouped into two scales. One of the scales is used to measure the affective relationship with learning and cognition, and the other one is for measuring the perception of the student to the use of statistics.

About this subject, Blanco [15] cited by García-Santillán et al. [23] carried out a critical review about pupils' ATS and described some test utilized to measure it in several kinds of students. In that study he refers Glencross et al. [27] who cited the most significant research in the Anglo-Saxon context [10,18,24,26,28-32].

### 2.1. Empirical Studies about Attitude toward Statistics

Auzmendi [6] identified, through multiple-regression analysis, significant predictors of attitudes, such as the student expectations for success or failure, the provision of the student toward computers, pre-training, motivation and anxiety. At the end of the course, in addition to the

expectations and previous training, assessments of the subject and teacher have also been useful predictors.

A similar study of Gil [7] evaluated a broad sample of students of Pedagogy, through exploratory factor analysis. Five factors were identified relating to the ATS: anxiety, interest, confidence, usefulness and value. It was also observed that, if students are aware of the usefulness of statistics, and they identify its relationship to the field of study, then they will have a favorable attitude. However, the anxiety of students and the lack of interest cause an unfavorable attitude.

Estrada [33] evaluated attitudes of teachers training students, and identified their relationship with personal variables like gender, previous training, specialty, and the level of statistical knowledge. These results suggest that teacher-training-student model almost always shows a positive ATS. The attitude of men and women toward statistics had no significant difference, and even there is no difference between students of different specialties.

Darías [34] evaluated the ATS scale in a sample of 188 people (male and female) of the first courses in Psychology at the Universidad de la Laguna. The results obtained by principal component factor analysis and varimax rotation, show four factors that determine the ATS: security, importance, usefulness, and wish to know. Safety factor is the one that provides more information, which allows understanding that anxiety determines the ATS.

In the same way, Carmona [35] evaluated the ATS on students of Psychology, and their results show that there is no relationship between attitudes and performance. However, it was found that capability in the field of the Mathematics generates a better ATS, while the age, gender, previous training, number of subjects taken and grades earned in high school, are not predictors of the ATS.

Muñoz [36] evaluated students of Pedagogy, Psychology, Psychopedagogy and Social Work through a multiple-regression analysis. The findings show that the most significant predictors of attitudes were: performance throughout the course, self-efficacy, perception of mathematical competence, and the value that is given to statistics at work. These factors contributed 65% to the total scale's score.

Of great significance are the results of Estrada [1], who evaluated professors, and demonstrated that the ATS of future teachers is favorable. According to the results, the most contributing factor is the cognitive ability, i.e.; professors believe that ability and skills are the top relevant factors for learning statistics. They also note that when teachers do not perceive the usefulness of statistics, the course is more challenging. These results even show that the years of education impact on attitude, as it increases the knowledge on the subject. Regarding gender, they perceive that women get slightly more negative ATS than men. It was also identified that ATS varies depending upon the specialty because some specialties demand more analytical skills than others.

Vanhoof et al. [37] studied the relationship between ATS, and scholarly results -short and long term- for college students who took statistics courses over five years in the specialty of educational sciences. The attitudes were evaluated with the ATS scale of Wise [10], which includes two sub-scales: ATC and ATF. The questionnaire was

applied at the beginning and the end of the university career of each participant.

Results show that during the first years, students' attitudes were more favorable to the course, more than toward study area. However, in the long term, when the students begin to write a thesis (fifth year), their ATS improve. According to the authors, it is because, on early years at university; students may ignore the applicability of the statistics' course.

In another study, Pierce [8] applies a pre and a post-test to 36 students from Ball University in three introductory courses: algebra, calculus, and statistics. In pre-test, students of all courses were sure that they could learn even if the course was challenging. Students' attitude in all courses was confident about their cognitive competence in mathematics and statistics. At post-test, there were almost no differences in students' answers. However, 60% of the students gave more value to the statistics in the post-test than in the pre-test.

Blanco [15] provides a comprehensive and updated overview of the empirical research on the Spanish undergraduate students' ATS. On their part Baloglu et al. [11] researched on the relationship between attitudes (toward the actual course and the field of study) and anxiety toward statistics of 95 seniors and 55 undergraduate students in social sciences. Canonical correlation analysis techniques were used. Results show negative ATS, i.e. anxiety toward courses and even toward the field of application.

Mondéjar [2] applied a new test to measure students' ATS with four dimensions: interest, anxiety, perceived usefulness for the professional career and usefulness of the statistical for their professional future. Results show that, when students adopt a more detailed study, they tend to find the course more attractive. Moreover, they perceive better usefulness in their professional future, and they have less anxiety in the subject.

Schild and Schild [38] applied a pre-test and post-test to 287 students from Augsburg College in order to measure ATS in four dimensions: difficulty, affection, cognitive competence, and value. When comparing the results of that study with the results obtained from Pierce [8], it is evident that students from both institutions consider that they have the ability to learn, even when they thought the course would be tough.

In other study, Vanhoof [39] says that ATS are relatively stable even over an extended period. These results are consistent with the description of attitude from McLeod [40] who indicates that attitudes are resistant to change, especially after high school, as has been demonstrated by Leong [41].

After the literature review, we could identify that the most utilized questionnaires to measure attitudes toward statistics are: SAS of Roberts and Bilderback [24], the ATS scale of Wise [10] and the Survey Attitudes toward Statistics (SATS) of Schau et al. [26].

Regarding questionnaires to measure anxiety toward statistics, the most used is the Statistics Anxiety Rating Scale (STARS) of Cruise et al. [42], followed by the Abbreviated Version of the Mathematics Anxiety Rating (MARS) of Suinn [43] and developed by Plake et al. [44]. The most significant results show that the majority of the scales that comprise these questionnaires demonstrated high internal consistency reliability. ATS has been

conceived theoretically in several ways: from a one-dimensional structure in the above-mentioned SAS [24], up to a composed of five dimensions in EAE of Auzmendi [6]. The same applies to the domain of anxiety toward statistics, with various proposals, which range from the single dimension of SAS [45] up to the six dimensions of STARS. In all cases, factorial analysis techniques were used. Some studies were conducted in research on the contents of the four questionnaires (STARS, ATS, QUQ, and SATS) of their respective items through evaluations of expert judges. These assessments, judgments about item-dimension consistency, are performed in the early stages of development. Regarding evidence of validity based on relationships among other variables, when the scores on the questionnaires have been used to predict the performance of students on the subjects of statistics, it has been found that both variables are weakly related. However, in those studies that have used more than one of the revised questionnaires, it has been found mostly high convergence among them.

In this regard, we do agree with Gal et al. [46] about that one of the main research problems within this field is the lack of academic models to guide the works. The lack of theoretical background is reflected, for example, at one of the most important aspects of the development and validation of a measuring instrument, namely the determination of its internal structure. However, with every obtained result in different empirical studies which have been reported in the last two decades, we may think that it has been tried to reach theoretical models to explain the phenomenon of anxiety and attitude toward mathematics and statistics.

With the theoretical arguments presented above, the research question is expressed as follows: Is there a significant statistical difference between the profiles of the mean score the students at Universidad Cristóbal Colón (UCC), Universidad Politécnica de Aguascalientes (UPA) and Universidad Autónoma de San Luis Potosí (UASLP) regarding their attitudes toward courses in statistics and toward the statistical field? Therefore, the aim of this research is to determine whether a significant statistical difference exists between the profiles of the mean scores of students at UCC, UPA and UASLP regarding the ATC and ATF.

Under the postulates of Wise: ATC and ATF, at UCC, UPA, and UASLP, are different.

### 3. Research Methodology

The present work is a non-experimental and cross-sectional study. Multivariate discriminant analysis is utilized in order to predict, explain and classify students from UCC, UPA, and UASLP, based on their ATC and ATF.

#### 3.1. Sample

The sample was selected by the criterion of non-probability sampling. It consisted of 672 students enrolled in mathematics courses at UCC, UPA and UASLP, all of them in Mexico. The selection criteria comprised including students who have completed at least one field of statistics, and that were available at the time the survey was applied. The instrument used was the ATS scale of

Wise [10]. The surveys were applied to students of several university careers as shown in Table 1. All groups of students took mathematics courses between second and third scholar year.

Table 1. Population by University

Bachelor	UCC	UASLP	UPA	Total
Business Management	49	73	44	166
Accounting	41	67	0	108
Economics	20	0	0	20
Marketing	35	74	0	109
International Markets and Businesses	83	0	0	83
Tourism Management	66	0	0	66
Industrial Engineering	0	0	30	30
Strategic Inf. Systems	0	0	30	30
Mechatronics' Engineering	0	0	30	30
Mechanical Engineering	0	0	30	30
Total	294	214	164	672

Source: own

### 3.2. Instrument

The ATS scale proposed by Wise [10] comprises 29 items, distributed in two sub-scales. The ATF sub-scale consists of the following 20 items, with reverse-keyed items indicated by an “(R)”: 1, 3, 5, 6(R), 9, 10(R), 11, 13, 14(R), 16(R), 17, 19, 20(R), 21, 22, 23, 24, 26, 28(R), and 29. The ATC sub-scale consists of the following nine items: 2(R), 4(R), 7(R), 8, 12(R), 15(R), 18(R), 25(R), and 27(R). To score the ATS, only sum the appropriate item scores for the sub-scales and/or total scale.

### 3.3. Statistic Procedure

From the data set that have previously been classified in a number of groups, we develop a discriminant analysis, which is considered as a regression analysis where the dependent variable is categorical and have as categories the labels of the groups, and the independent variables are continuous and determine the groups to which the objects belong.

Therefore, it is intended to find linear relationships between continuous variables that best discriminates the groups given to objects. Subsequently, a decision rule that assigns a new object classification previously unknown, to one of the groups prefixed with a certain degree of risk, is built.

In this way, it is now necessary to emphasize a range of restrictions or assumptions.

If we have a categorical variable and the remaining variables are interval or ratio and are independent with respect to the variable, it is necessary to have at least two groups, and each group of two or more cases is needed. The number of discriminant variables must be less than the number of objects minus 2:  $x_1, \dots, x_p$ , where  $p < (n - 2)$  and  $n$  is the number of objects. No discriminant variable may be a linear combination of other discriminant variables.

The maximum number of discriminant functions is equal to the minimum value of the number of variables and the number of groups minus 1 (with  $q$  groups,  $(q - 1)$  discriminant functions). The covariance matrices of each group must be approximately equal. Continuous variables must follow a multivariate normal distribution.

### 3.4. Mathematical Model

Starting from  $q$  groups in which are assigned to, a series of objects and  $p$  variables measured on them  $(x_1, \dots, x_p)$ , it comes to obtaining for each object a set of scores indicating the group to which they belong  $(y_1, \dots, y_m)$  so as to be linear functions of  $x_1, \dots, x_p$

$$y_1 = a_{11}x_1 + \dots + a_{1p}x_p + a_{10}$$

$$\dots\dots\dots$$

$$y_m = a_{m1}x_1 + \dots + a_{mp}x_p + a_{m0}$$

Where  $m = \min(q - 1, p)$ , in a way that discriminates and separates as much possible the objects to the  $q$  groups. These linear combinations of the  $p$  variables should maximize the variance between the groups and minimize the variance within the groups.

#### 3.4.1. Variance Decomposition

The total variability of the sample can be decomposed in variability within the groups and between groups. Thus, we start from:

$$Cov(x_j, x_{j'}) = \frac{1}{n} \sum_{i=1}^n (x_{ij} - \bar{x}_j)(x_{ij'} - \bar{x}_{j'}) \tag{2}$$

May be considered the mean of the variable in each of the groups  $I_1, \dots, I_q$ , i.e.

$$\bar{x}_{kj} = \frac{1}{n_k} \sum_{i \in I_k} x_{ij} \tag{3}$$

In this way, the total average of the variable  $x_j$  may be expressed as a function of the mean of each group. So, we have:

$$\sum_{i \in I_k} x_{ij} = n_k \bar{x}_{kj} \tag{4}$$

Then:

$$\bar{x}_j = \frac{1}{n} \sum_{i=1}^n x_{ij} = \frac{1}{n} \sum_{k=1}^q \sum_{i \in I_k} x_{ij} = \frac{1}{n} \sum_{k=1}^q n_k \bar{x}_{kj} = \sum_{k=1}^q \frac{n_k}{n} \bar{x}_{kj} \tag{5}$$

As we come to:

$$Cov(x_j, x_{j'}) = \frac{1}{n} \sum_{i=1}^n (x_{ij} - \bar{x}_j)(x_{ij'} - \bar{x}_{j'}) \tag{6}$$

If placed at each of the terms:

$$(x_{ij} - \bar{x}_j) = (x_{ij} - \bar{x}_{kj}) + (\bar{x}_{kj} - \bar{x}_j)$$

$$(x_{ij'} - \bar{x}_{j'}) = (x_{ij'} - \bar{x}_{kj'}) + (\bar{x}_{kj'} - \bar{x}_{j'}) \tag{7}$$

Simplifying, we have:

$$Cov(x_j, x_{j'}) = \frac{1}{n} \sum_{i=1}^n (x_{ij} - \bar{x}_j)(x_{ij'} - \bar{x}_{j'}) + \sum_{k=1}^q \frac{n_k}{n} (\bar{x}_{kj} - \bar{x}_j)(\bar{x}_{kj'} - \bar{x}_{j'}) = d(x_j, x_{j'}) + e(x_j, x_{j'}) \tag{8}$$

The total covariance matrix is equal to the covariance within the groups, plus the covariance between groups. If

we name  $t(x_j, x_{j'})$  the total covariance between  $x_j$  and  $x_{j'}$  (without distinguishing groups), then the above is expressed by:

$$t(x_j, x_{j'}) = d(x_j, x_{j'}) + e(x_j, x_{j'}). \tag{9}$$

In a matrix form, this is equal to:

$$T = E + D \tag{10}$$

Where:

- T = total covariance matrix
- E = covariance matrix between groups
- D = covariance matrix within groups

### 3.4.2. Extraction of Discriminant Functions

For extracting discriminant functions, it is given starting from  $x_1, \dots, x_p$  variable observed in  $k$  groups,  $m$  functions  $y_1, \dots, y_m$  of the form

$$y_i = a_{i1}x_1 + \dots + a_{ip}x_p + a_{i0} \tag{11}$$

Where  $m = \min(q - 1, p)$ , such which  $\text{corr}(y_i, y_j) = 0$  for all  $i \neq j$ .

If the variables  $x_1, \dots, x_p$  are typified, then the functions

$$y_i = a_{i1}x_1 + \dots + a_{ip}x_p \tag{12}$$

For  $i = 1, \dots, m$ , are called canonical discriminant functions. The functions  $y_1, \dots, y_m$  are extracted such that:

- (i)  $y_1$  either the linear combination of  $x_1, \dots, x_p$  which provides the greatest discrimination between groups.
- (ii)  $y_2$  either the linear combination of  $x_1, \dots, x_p$  which provides the greatest discrimination between groups, after  $y_1$ , such which  $\text{corr}(y_i, y_2) = 0$ .

Generally,  $y_i$  is the linear combination of  $x_1, \dots, x_p$  which provides the greatest discrimination between groups, after of  $y_{i-1}$  and such which  $\text{corr}(y_i, y_j) = 0$  for  $j = 1, \dots, (i - 1)$ .

Continuing with the matrix function, a linear function of  $x_1, \dots, x_p$  is searched:  $y = a'x$ , therefore, we have:

$$\text{Var} = (y) = a'Ta = a'Ea + a'Da \tag{13}$$

That is the variation between the groups and variation within groups. Hence, if we want to maximize the variability between groups to be able discriminate better, then we have:

$$\max\left(\frac{a'Ea}{a'Ta}\right) \tag{14}$$

If we consider the function to minimize the variance among groups in relation to the total variance, then we have:

$$f(a) = \frac{a'Ea}{a'Ta} \tag{15}$$

Considering that  $f$  is a homogeneous function, i.e.  $f(a) = f(\mu a)$  for all,  $\mu \in R$ , which implies that calculating Eq. (14) is equal to calculate:

$$\begin{aligned} &\max(a'Ea) \\ &\text{such\_that(or\_similar\_way)} \\ &a'Ta = 1 \end{aligned} \tag{16}$$

Now, the Lagrange multipliers are defined as:

$$L = a'Ea - \lambda(a'Ta - 1) \tag{17}$$

To subsequently calculate its derivate:

$$\begin{aligned} \frac{\partial L}{\partial a} &= 0, \\ \frac{\partial L}{\partial a} &= 2Ea - 2\lambda Ta = 0 \Rightarrow \\ Ea &= \lambda Ta \Rightarrow \\ (T^{-1}E)a &= \lambda a \end{aligned} \tag{18}$$

Therefore, the eigenvector associated with the first discriminant function, it is, from the matrix  $T^{-1}E$  (which usually is not symmetrical), as  $Ea = \lambda Ta$ ,

$$a'Ea = \lambda a'Ta = \lambda \tag{19}$$

Subsequently, the eigenvector associated with the maximum eigenvalue is taken; the function that collects the maximum discriminating power is obtained. This eigenvalue associated with the discriminant function shows the proportion of the total variance explained by the  $m$  discriminant function, which collects the variable  $y_i$ .

In this way we continue by calculating the eigenvectors of the matrix  $T^{-1}E$  associated with the chosen eigenvalues in descending order, all this, to get more discriminant functions:

$$\begin{aligned} a'_2 &\Rightarrow a'_2x = y_2 \\ &\cdot \\ \dots & \\ &\cdot \\ a'_m &\Rightarrow a'_mx = y_m \end{aligned} \tag{20}$$

Where  $m = \min(q-1, p)$

These independent linear vectors, give us un-correlated functions among self.

Finally, with the sum of all the eigenvalues  $\sum_{i=1}^m \lambda_i$ , the proportion of variance explained is obtained, or is retained when only consider axes or discriminant functions. As a consequence, the percentage by  $y_i$ , from the total variance explained by  $y_1, \dots, y_m$  is:

$$\frac{\lambda_i}{\sum_{i=1}^m \lambda_i} * 100\% \tag{21}$$

With the procedure of discriminant analysis in SPSS v.19 we get the following results.

## 4. Data Analysis

Firstly, we carried out a reliability analysis of the obtained data. Therefore, a reliability test was performed using the Cronbach's alpha coefficient ( $\alpha$ ). Cronbach's alpha ( $\alpha$ ) is a squared correlation coefficient, which measures the consistency of the items averaging all correlations among all questions [23]. The closer it gets to 1, means the better reliability, considering that starting from 0.80 it is a very acceptable value. Thus, the Cronbach's alpha can be set as a function of the number of items and the average of correlations among the items

$$\rho = \frac{N * \bar{r}}{1 + (N - 1) * \bar{r}} \quad (22)$$

Where: N = Number of items (or latent variables),  $\bar{r}$  = average of correlations among the items.

The results are shown in Table 2.

Table 2. Cronbach's Alpha

Cronbach's alpha overall: 0.846, N of items: 29, N=672					
ATF subscale			ATC subscale		
1	0.842	17	0.848	2	0.842
3	0.843	19	0.842	4	0.840
5	0.844	20	0.833	7	0.834
6	0.836	21	0.840	8	0.840
9	0.842	22	0.841	12	0.834
10	0.836	23	0.840	15	0.848
11	0.847	24	0.841	18	0.839
13	0.840	26	0.842	25	0.837
14	0.872	28	0.835	27	0.836
16	0.835	29	0.842		

Source: own

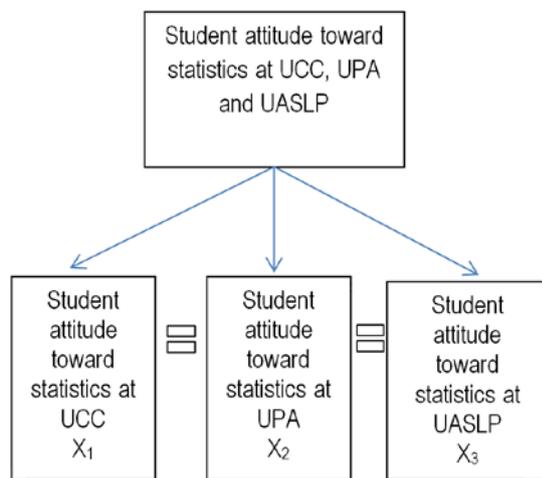


Figure 1. Conceptual model

The result obtained from the total items is (0.846) and individually grouped into two dimensions -ATF and ATC-

all there is more than 0.8, both are very acceptable ( $\alpha > 0.8$ ) [47], therefore, the instruments (the scale) have the characteristics of consistency and reliability which is required for the study, so the validity of the test is confirmed.

The hypothesis, which states that there is a difference between students from UCC, UPA, and UASLP regarding mean scores of students' ATS in relation to the field and the course, is defined as the conceptual model shown in Figure 1.

The discriminant analysis technique was used to test the mean difference.  $D_2$  of Mahalanobis was used as the criterion for selecting variables that best discriminate in the application of discriminant analysis to assess the student attitude.

### 5. Results

Table 3 shows the mean values of the variables, which indicate that groups are significantly different because the values of Wilks' lambda and the F value is less than 0.05. It suggests that the ATS -both, to the field and to the course- shows significant differences in the three groups.

Table 3. Descriptive Statistics of the Groups

Dependent variable	Means		Size of sample
	Field	Course	
UCC	68.363	22.363	294
UASLP	71.378	25.747	214
UPA	70.615	30.682	164
Total	69.873	25.471	672
Contrast equality of group means			
Wilks' lambda	0.972	0.731	
F	9.524	122.990	
Sig.	0.000	0.000	

Source: own

Table 4 shows the overall results of stepwise discriminant analysis and describes that the variables "course and field", are significant discriminators based on Wilks' lambda (Sig = 0.000) and the minimum values of the  $D_2$  of Mahalanobis (Sig = 0.000).

Table 4. Summary Results

Step	Action It entered	Wilks' s lambda		Minimum $D_2$		Among groups		
		Value	Sig	Value	Sig			
1	course	0.731	0.000	0.009	0.000	UASLP y UPA		
2	field	0.720	0.000	0.385	0.000	UCC y UASLP		
Canonical Discriminant Functions								
Function	Eigenvalue	Function	Accumulated	Canonical Correlation	Wilks's lambda	X <sup>2</sup>	df	Sig.
1	0.369	96.1	96.1	0.519	0.720	219.700	4	0.000
2	0.015	3.9	100.0	0.121	0.985	9.891	1	0.002

Source: own

Furthermore, the significance of the canonical discriminant functions (course Sig = 0.00; field Sig = 0.002) measured by the Chi-square statistic, are shown in Table 4. Similarly, the variance explained by each function is displayed, the value of the first function is 26.9% (0.5192) and the second is 1.4% (0.1212). Whereas, the variance explained by the two functions is 96.1%.

The Wilk's lambda values in Table 4, have a critical level of significance (Sig = 0.00) less than 0.05, indicating that the full model allows distinguishing significantly between groups. The Wilks' lambda value of the second function takes a value very close to one (0.985) and its significance is less than 0.05 therefore, it can be said with

95% certainty that the second function allows to discriminate between at least two of the groups.

Table 5 shows the location of the centroid of each of the discriminant functions. The first one distinguishes the UCC group (negative centroid) from the groups of UASLP and UPA (whose centroids are positive). The second function distinguishes the UASLP group (whose centroid is positive) from the groups of UPA and UCC (that are negative). Since the first function has managed to explain the maximum differences of UPA, with respect to UASLP and UCC, it can be inferred that the second function discriminates between groups that have remained closer.

That is; the students' ATC at UPA are different from the students' attitudes at UCC. However, students' ATF at UASLP are different from what was observed at UCC and UPA.

**Table 5. Centroid of Discriminant Functions**

Group	Function 1	Function 2
UCC	-0.575	-0.076
UASLP	0.060	0.178
UPA	0.952	-0.096

Source: own

Table 6 shows the loads of the discriminant functions. It indicates the group in which a student may be assigned when it presents certain ATS. For instance, if a student shows ATF, is assigned to the UPA. In the same way, a student that has ATC, then, is a student corresponding to UASLP.

**Table 6. Coefficients and Loads of Discriminant Functions**

Independent Variable	Weightings		Loads	
	1	2	1	2
Field	0.054	1.009	0.999	-0.053
Courses	0.991	-0.198	0.196	0.981

Source: own

Once significant discriminant functions have been identified; the next step in the analysis is to examine the overall fit of the considered discriminant functions. This valuation is carried out to assess discriminant Z scores because it provides direct measurements to compare the observations for each function. In this method, the values that correspond to the variable "field" (25) and the variable "course" (63) are included. Subsequently, a classification score for each group is calculated. Moreover, for that observation, it is classified in the group with the highest score classification. In this case, the value of  $Z_1 = 35.05$ ,  $Z_2 = 34.8$  and  $Z_3 = 32.645$ , which indicates that student correspond to UCC.

$$\begin{aligned}
 Z_1 &= -40.847 + 0.542course + 0.994 field \\
 Z_2 &= -46.227 + 0.648course + 1.029 field \\
 Z_3 &= -49.341 + 0.820course + 1.002 field
 \end{aligned}
 \tag{23}$$

The last step in the assessment of adjustment of the model consists of determining the level of predictive accuracy of the discriminant functions. The findings show in Table 7 that both functions achieve a good degree of precision because the hit ratio analysis of the sample is 55.2%  $[(231 + 58 + 82) / 672]$  this value is compared with the criterion of proportional randomness ( $C_{PROP}$ ) and the criterion of maximum randomness ( $C_{max}$ ).

**Table 7. Classification Matrix**

From	Number of cases	Group membership		
		UCC	UASLP	UPA
UCC	294	231	28	35
		78.6%	9.5%	11.9%
UASLP	214	113	58	43
		52.8%	27.1%	20.1%
UPA	164	58	24	82
		35.4%	14.6%	50.0%

Source: own

As the value of  $C_{max}$  is 43.8% (previously probability of groups: UCC =.438; UASLP =.318; UPA =.244) and the  $C_{PROP}$  is 35.24%  $[(.438)^2 + (.318)^2 + (.244)^2]$ , then  $C_{max}$  is used to set a threshold for comparison. If the threshold of 25% larger than the criterion value is set, the hit radius must exceed 54.75 (43.8 x 1.25). The radius value of

successes (55.2%) is higher than the threshold fixed (54.75%). Therefore, there is a good model fit [47].

The last measure of classification accuracy "Q of Press" is 14.55, this value is greater than the criterion value of 6.63 (sig=0.01), which indicates the statistical significance of the discriminant functions.

## 6. Discussion and Conclusion

It is concluded that the statistical results of this analysis are satisfactory. It is not possible to reject the general hypothesis which states that the means of the ATC and ATF of statistics for the students from UCC, UPA, and UASLP are different. This statement is based on statistically significant variables in the estimated functions, as well as the higher percentage of correct classification (57.4%).

Both explanatory variables: ATC and ATF are different in the three universities studied. The ATC of students at UPA are different from the students at UCC. The ATF of students at UASLP are distinct from students at UCC and UPA.

The results are similar to those reported by Pierce [8], who showed that the ATS among students from different institutions are not distinct; however, the vast majority perceives statistics courses as challenging, and therefore their attitude is not very favorable. In contrast, the outcomes obtained in this study do not match to those exposed by Vanhoof [39] who mentioned that when students see the application of this subject in the professional field better appreciate the value of statistics.

The difference in the ATS among students of the universities under study exists because UPA focuses on practical applications of statistics, whereas UCC and UASLP are focused on providing more theoretical knowledge.

## Further Research

It is important to make comparisons between careers who are studying students of the different universities which have been reviewed, in order to determine if there are differences regarding the field of statistics among students, considering that the sample is composed of students of different careers.

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## Statement of Competing Interests

The authors have no competing interests.

## List of Abbreviations

ATC: Attitudes toward Course  
 ATF: Attitudes toward Field  
 ATS: Attitudes toward Statistics  
 CMAX: Criterion of maximum randomness  
 CPROP: Criterion of proportional randomness  
 EAE: Attitude Scale Toward Statistics  
 MARS: Abbreviated Version of the Mathematics Anxiety Rating  
 SAS: Statistics Attitudes Survey  
 SATS: Survey Attitudes toward Statistics  
 STARS: Statistics Anxiety Rating Scale  
 UASLP: Universidad Autónoma de San Luis Potosí  
 UCC: Universidad Cristóbal Colón  
 UPA: Universidad Politécnica de Aguascalientes

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