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# Evaluation of attitudes towards statistics in preservice teachers

## *Evaluación de las actitudes hacia la estadística de maestros en formación*

**Navarro-Asencio, Enrique** [1], **Asensio-Muñoz, Inmaculada** [1], **Arroyo-Resino, Delia** [2], **& Ruiz-De Miguel, Covadonga** [1]

[1] Complutense University of Madrid (Spain), [2] International University of La Rioja (Spain)

## Abstract

The evaluation of future teachers' attitudes towards statistics is of interest due to the importance that statistical training has in current society for citizens, in general, and, specifically, due to its relationship with scientific literacy in teachers. As evaluations must be based on valid and reliable measurements, such work largely aims to contribute metric outcomes. The present work consisted of obtaining evidence of the consistency and validity of the scale of attitudes towards statistics (EAE) when administered within a group of 542 university students undertaking teacher training degrees. After describing the group under study, the construct was considered from a multivariate approach suitable for ordinal data, employing confirmatory factor analysis (ULSMV) and decision trees (CHAID and CART). Outcomes indicate that examined students did not have positive attitudes and considered their mastery of statistics to be insufficient for conducting educational research. On the other hand, students displayed interest in being up-to-date and able to discriminate fact from fiction. Following the evaluation of eleven measurement models and their associated fit indices, the present study concludes by present evidence of the convergent validity and consistency of a construct structure pertaining to five factors and 24 items. Additionally, the usefulness of EAE items in predicting determined criteria was evidenced (self-evaluation of performance and indicators of the importance attributed by future teachers to science and research in their profession).

**Keywords:** attitude, statistics, teacher training, university, validity.

## Resumen

La evaluación de las actitudes hacia la estadística de los futuros profesores alcanza interés por la importancia que la formación en esta disciplina tiene en la sociedad actual, para la ciudadanía en general, y, específicamente, por su relación con la alfabetización científica de los maestros. Dado que un elemento básico en la evaluación es que se apoye en medidas válidas y fiables, el objetivo final del presente trabajo es fundamentalmente métrico y consiste en obtener evidencias de consistencia y validez estructural y criterial de la Escala de Actitudes hacia la Estadística (EAE), que se aplica a 542 estudiantes de los grados de Maestro en Educación Primaria e Infantil. Después de describir al colectivo estudiado, se aborda el constructo desde un enfoque multivariado adecuado para datos ordinales, con análisis factorial confirmatorio (ULSMV) y árboles de decisión (CHAID y CART). Los resultados indican que los estudiantes consultados no tienen unas actitudes muy positivas y consideran que su manejo de la estadística es insuficiente para realizar investigación, pero muestran interés por estar actualizados y poder discriminar entre lo cierto y lo falso. Tras evaluar once modelos de medida, se concluye aportando evidencias de la convergencia y consistencia de un constructo con cinco dimensiones y 24 ítems, con índices de ajuste aceptables en este colectivo. Además, se evidencia la utilidad de los ítems de la EAE para predecir los criterios utilizados, autoevaluación del desempeño e indicadores de la importancia que los futuros maestros otorgan a la ciencia y a la investigación en su profesión.

**Palabras clave:** actitud, estadística, formación de profesores, universidad, validez.

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***Corresponding author / Autor de contacto:*** Enrique Navarro Asencio. Complutense University of Madrid. Faculty of Education. C/ Rector Royo Villanova nº 1, CP 28040, Madrid, Spain. correo-e: enriquen@ucm.es

Statistics play a fundamental role in the development of the academic, working and everyday life of citizens in the information society (Batanero, 2013) or, as Martínez and Soto call it, the "data society" (2019), in which we live. Despite this, in university classrooms, particularly in the area of social sciences, it is common to find students who believe themselves incapable of coping with a task before they have even made an attempt at it. This is influenced by cognitive, affective and behavioral factors, given that it is easier for humans, in general, to undertake metaphorical, associative or causal thinking than to think in statistical terms (Kahneman, 2012). Furthermore, students, especially those who have more limited prior education in quantitative matters (Blanco, 2004), have a fear of being faced with statistics (Finney and Schraw, 2003). This makes statistics one of the least favorite subjects overall (Lodico et al., 2004), with it being frequently put off and postponed to the final years of the degree. Affective factors have a substantial influence on shaping attitudes, which are particularly pertinent because they are associated with performance in such a way that negative attitudes are generally correlated with academic failure (Carmona, 2004; Cimpoero & Roman, 2018; Estrada et al., 2004; Evans, 2007; León & Vaiman, 2013; Vanhoof et al., 2011) and complicate acquisition of the necessary skills for future development in the professional setting (Meller & Rappaport, 2004).

It is not uncommon for students on teaching degrees at the few universities which include statistical skills teaching (Arteaga & Navarro, 2013) to manifest these negative feelings (Ruiz de Miguel, 2015) and for the teaching and learning of statistics on teacher-training courses to be demotivating, not just for students but, also, for lecturers. Recognizing and dealing with the low regard for statistics among teachers on learning courses is important as, otherwise, undesirable consequences may result. Firstly, just as is the case with negative attitudes towards mathematics (Caballero et al., 2007; Fernández & Aguirre 2010; Gómez & Fernández, 2018; Maz-Machado et al., 2014; Sánchez et al., 2011; Valle et al., 2016), it is very easy for such negativity to be transferred to compulsory education classrooms (Naya et al., 2014), resulting in a never-ending circle of aversion to numerical issues. Secondly, this may also partly explain why so few teachers participate in research during their professional careers (Papanastasiou & Schumacker, 2014), with this representing an obstacle to scientific development in the academic field.

The incorporation of statistics into teaching degree courses is justified by the affiliation of these university studies with a field in which statistics forms one of the basic materials, serving as a bridge between science and professional practice. In this regard, statistical and scientific literacy in teachers is based on the three motives stated at the start of this article. In the academic and working sectors, it is necessary, firstly, to minimize the evidence gap which has emerged in relation to research and classroom teaching (Camilli et al., 2020) as a means to improvement and staying current. Statistical learning is rooted in the development of skills which allow teachers to "establish cordial, permanent and reciprocal contact with science or sciences in which the knowledge base open to professionals is generated and stimulated" (Asensio et al., 2015, p. 220). It also has its foundations in the handling of the language of statistics and science so that teachers can be intelligent users of the outcomes produced by educational research (Gaviria, 2015). Secondly, although it is clear that not all teachers are obliged to become researchers as many may have roles in which it is not really necessary to make scientific contributions to the development or advancement of education, at least a certain percentage of graduates will undertake a master's or PhD studies which will provide them with the means to be a researcher in education. Finally, with regards to the day-to-day, scientific literacy helps teachers understand and effectively translate the role that scientific evidence has in the development of critical thinking. Discriminating between what is true, likely to be true or false is particularly relevant in current society which is characterized by its dynamic modernity. In this reality, all knowledge appears to be unstable (Bauman, 2013) but, as stated by Cordero (2009), the imprint left by scientific training enables citizens to challenge, reflect and act based on their own substantiated criteria.

Research on attitudes towards statistics began around the middle of the last century (Bending & Hughes, 1954), advancing steadily since the 1980s (Blanco, 2008; Estrada, 2009; Mondéjar & Vargas, 2010) to the present day. Attitudes are beliefs and cognitions which have been learnt with a heavy affective load. Individuals are predisposed to act in accordance with their attitudes and beliefs (Rodríguez Feijoo, 2011). They are complex constructs consisting of a range of emotions and feelings which are not innate yet are stable, and slowly develop (Gal et al., 1997) based on experiences in educational contexts. They emerge at early ages (Dutton & Blum, 1968), starting off as positive (Auzmendi, 1992) but changing (Callahan, 1971) when negative experiences are lived (Suydam, 1984), with these modified attitudes and beliefs being maintained during subsequent academic years (Aiken, 1972).

The measurement of attitudes towards statistics has traditionally been based on attitude scales towards mathematics and, with the exception of a few cases in which semantic differentials were used (Carmona, 2004), is usually centered on Likert-type scales (Blanco, 2008). With these tools, attitude strength is indicated through the sum of scores given to different positively or negatively framed statements. Table 1 describes the main instruments used on an international scale.

Table 1. Main surveys for measuring attitudes towards statistics

| INSTRUMENT | AUTHORS | DESCRIPTION |
|---|---|---|
| *Statistics attitude survey* (SAS) | Roberts & Bilderback (1980) | Based on work conducted by Dutton (1954), this tool measures a general characteristic which moderately predicts achievement (Waters et al., 1988) from 33 items rated on a 5-point Likert scale and has a reliability index of .90 (Roberts and Saxe, 1982). |
| *Attitudes toward statistics* (ATS) | Wise (1985) | Emerged as an alternative to the SAS, measuring implementation more than attitudes. Contains 29 items grouped into two sub-scales (affective and cognitive), with a reliability index of .90. |
| Survey of attitudes toward statistics (SATS)<br>SATS-28<br>SATS.36 | Schau, Stevens, Dauphine & del Vecchio (1995)<br><br>Schau (2003) | • Version 1: 28 items rated on a 7-point Likert scale. Overall tool and sub-scales correlate acceptably with the ATS. Acceptable reliability shown for all four factors: affect (.85), cognitive skills (.83), value (.85) and difficulty (.77).<br>• Version with 36 items and six factors (following the addition of effort and interest) |

*Note: Elaborated by the authors*

Nolan et al. (2012) published a systematic review of the tools' psychometric characteristics to highlight the large amount of evidence regarding its content, structure, and convergent, discriminant and predictive validity existing for these four instruments. In the Spanish context, Blanco (2008) presented a critical review highlighting the PhD conducted by Auzmendi in 1991 and published in 1992 as pioneering work (Auzmendi, 1992). Subsequently, other work can be highlighted such as the *Escala de Actitudes hacia la Estadística* by Velandrino & Parodi (1999), the *Cuestionario de Actitudes hacia la Estadística-CAE* by Carmona (2002) (which uses the SATS as a reference for convergent validity), the *Escala de Actitudes hacia la Estadística* by Estrada (2002) and the *Escala de Actitudes* *hacia la Estadística - EAHE* by Muñoz (2002). The SAS, ATS and SATS scales have also been applied in Spanish. Aside from the studies covered in the review by Blanco (2008), one of the most recent works worth citing is the adaptation of the SATS-36 by Rodríguez-Santero & Gil-Flores (2019). With a sample of educational sciences students at the University of Seville, this study produced the best adjustment indices of existing studies for a five-factor model with correlated errors ($\chi 2$ /df= 2.19, GFI (goodness of fit index) = .873, CFI (comparative fit index) =.878 and RMSEA (root mean square error of approximation) =.055). With regard to teachers' attitudes towards statistics in practice or training, it is worth highlighting research conducted by Estrada (2002), Estrada et al. (2004, 2010), López & Molina, (2016), Ordóñez et al. (2019), Ruiz de Miguel (2015), Vásquez et al. (2019) and Zapata & Rocha (2011).

Table 2. Main validation studies of the EAE (Auzmendi, 1992) in university students and dimensionality.

| | |
|---|---|
| Auzmendi (1992) with 2,052 Basque students undertaking different types of degrees | A 5-point Likert-type scale with 25 items (from totally disagree to totally agree) divided into 5 factors: usefulness, stress, confidence, pleasure and motivation. Explained 60.7% of overall model variance, applying principal axis factor analysis and a varimax rotation. Reliability of .90 produced for the overall scale, relative to .80, .84, .84, .83 and .71 for each of the identified factors. Produced a correlation of .86 with the SAS (concurrent validity) |
| Darías (2000) with 188 psychology students in the Canary Islands | Four-factor solution using the same factor analysis approach as Auzmendi, explaining 53.5% of variance. Item 25 discarded. |
| Méndez & Macía (2007) with 168 psychology students in Chilean universities | Four-factor solution explaining 48.9% of variance using exploratory factor analysis and a common factor extraction method (principal axes). Suitable for variables with an ordinal level of measurement and orthogonal equamax rotation. Alpha reliability of .85 for the overall scale and .90, .81, .73 and .79 for the individual factors. The items also presented good discrimination indices. Item 20 discarded. |
| Tejero & Castro (2011) with 145 physical education and sports science students at public universities | Tested the models developed by Auzmendi (1992), Darías (2000) & Méndez & Macía (2007) using a common factor method (maximum likelihood) and confirmatory analysis. Achieved a 3-factor solution with 12 items which explained 68% of variance (GFI=.91, CFI=.95 and RMSEA=.69). Produced an overall reliability of .87, and reliability of .87, .83 and .76 for the factors. |

*Note: Elaborated by the authors*

The present paper is based on individuals undergoing teacher training. Their attitudes towards statistics were measured using the *Escala de Actitudes hacia la Estadística (EAE)* proposed by Auzmendi (1992). Operationalization of this construct may enable early identification of developmental issues relating to this subject and attitudes linked to the importance that future teachers give to science and research in this profession. In order to ensure its suitability as an evaluation instrument, it is necessary to obtain evidence about its structure as, despite the number of studies carried out (summarized in Table 2), construct dimensionality has yet to be unequivocally demonstrated. The present study is, therefore, a validation study, in accordance with the definition of validation provided in reviews conducted by the AERA, APA and NCME (2014). This description considers evaluation as a process of accumulating evidence on a given measurement for a given purpose. In this sense, the intended outcome of the measurement tool always defines the approach taken to validation.

As a result, confirmatory factor analysis (CFA) and decision trees - both multivariate techniques adapted to ordinal data - were employed to pursue the aims of the present research which were; 1) identify dimensionality of the construct "attitudes towards statistics", and examine the convergent validity and internal consistency of the proposed measurement model, and 2) identify the usefulness of EAE items for identifying the attitudes which may predict the perceptions of teaching students about research and science, establishing which are most effective at discriminating between students who consider themselves to be more or less prepared to deal with statistics.

## Method

Data was gathered from an incidental sample of 542 students undertaking primary and nursery level teaching degrees at the Universidad Complutense of Madrid. Participants were informed about study aims and voluntarily responded to the EAE, together with three other questions which were used as criteria in predictive validity analyses. The survey was administered in person to 1st to 3rd year students (82.6% of the sample) and online to 4th year students who were on work experience placements at the time. As there is no specific deontological code in education research, the study respected the rights of participants and data confidentiality in line with the Declaration of Helsinki of the World Medical Association.

In order to carry out the required analysis to address the main study aim, the Mplus program was used. The chosen strategy was to examined the models described in Table 2 alongside a number of alternatives. To this end, negative items were reversed (2, 5, 7, 10, 12, 15, 16, 17, 22 and 25). These corresponded to factors 2 and 5 in the original model (thus, the latter becomes "demotivation"). After establishing the lack of multivariate normality based on a polychoric correlation matrix, parameters were estimated according to the robust unweighted least squares (ULSMV) method, deemed suitable in cases such as the present study (Li, 2014; Xia, 2016). In the model evaluation phase, a number of standardized indices are used. The robust Chi-square ($\chi 2$ /df) was used to assess overall model fit, with values of between 3 and 5 being considered acceptable. RMSEA analysis assessed the residual matrix, with acceptable values being lower than .08. Finally, CFI (comparative fit index) and TLI (*Tucker-Lewis Index*) indicated good fit when values were above .90. According to Hu & Bentler (1999), acceptable fit is sufficient can be examined through a combination of these indices. Construct dimensionality was examined by investigating the relationship between observed and latent variables and between the latent variables themselves. Finally, convergent validity was assessed according to two indicators. Firstly, average variance extracted (AVE) was calculated by summing the squared multiple correlations and the total sum of each variable (Pi) and dividing by the total number of items in the construct as shown in formula (1).

$$AVE = \frac{\sum_{i=1}^{N} P_i^2}{n} \qquad (1)$$

Furthermore, internal consistency of the dimensions was estimated by means of Cronbach's alpha (polychoric correlation matrix) and composite reliability (CR), adding the factor loadings and error variance (e) into formula (2),

$$FC = \frac{(\sum_{i=1}^{n} P_i)^2}{(\sum_{i=1}^{n} P_i)^2 + (\sum_{i=1}^{n} e_i)} \qquad (2)$$

In this case, the error variance of an item is the result of subtracting the squared factor loading from 1, as shown in formula (3).

$$e_i = 1 - P_i^2 \qquad (3)$$

In order to achieve the second objective, the regression tree segmentation technique was used. SPSS was employed to calculate the CHAID (chi automatic interaction detection) algorithm according to classification techniques (Kass, 1980). This enables determination of the significance of average differences pertaining to chi-square and CART (classification and regression trees) (Breiman et al., 1984). This analysis places items in a hierarchy according to their standardized importance in a supervised process. Decision trees offer an alternative type of multivariate analysis for non-parametric models and have been proven to be useful in the validation of educational measures (Álvarez Benítez & Asensio-Muñoz, 2020; Blanco et al., 2017). They are called trees because the flow diagrams which result consist of branches and leaves or nodes. These represent divisions in the population of interest into sub-groups based on predictor variable outcomes in relation to chosen criteria (Tourón et al., 2018). In this case, the 25 items were used as predictors, just as they appear in the original EAE scale. For criteria, three items responded to on a 5-point Likert scale (Table 3) were used. These were used as indicators of achievement (Figure 2) and student perceptions regarding being up-to-date and scientific evidence (Figures 3, 4 and 5).

## Results

Univariate descriptive statistics and bivariate correlations for each item are presented in Table 3.

Table 3. Description of EAE items and Spearman correlations with the criteria

| EAE ITEMS | N | Min | Max | Mean | S | Rho1º | Rho2º | Rho3º |
|---|---|---|---|---|---|---|---|---|
| 1.I see statistics as a very important subject for my degree | 539 | 1 | 5 | 2.73 | .95 | .14$^{**}$ | .10$^{*}$ | .11$^{*}$ |
| 2.I'm not very good at statistics | 539 | 1 | 5 | 2.82 | 1.22 | -.18$^{**}$ | .00 | .04 |
| 3.I'm not at all worried about studying or working with statistics | 540 | 1 | 5 | 3.11 | 1.12 | .15$^{**}$ | -.01 | .06 |
| 4.I enjoy using statistics | 540 | 1 | 5 | 2.05 | 1.04 | .18$^{**}$ | .05 | .05 |
| 5.Statistics is too theoretical to be of practical use for the average professional | 540 | 1 | 5 | 2.54 | 1.03 | -.04 | -.10$^{*}$ | -.05 |
| 6.I want to have more in-depth knowledge of statistics | 540 | 1 | 5 | 2.68 | 1.11 | .90$^{*}$ | .06 | .08 |
| 7.Statistics is one of the subjects I fear the most | 541 | 1 | 5 | 2.71 | 1.23 | -.08 | -.02 | .02 |
| 8.I have confidence in my abilities when faced with a statistical problem | 540 | 1 | 5 | 3.08 | 1.08 | .15$^{**}$ | -.06 | -.05 |
| 9.I enjoy talking about statistics with others | 540 | 1 | 5 | 1.68 | .90 | .14$^{**}$ | .05 | .00 |
| 10.Statistics can be useful to someone who does research but not to the average professional | 540 | 1 | 5 | 2.85 | 1.08 | -.08 | -.07 | -.14$^{**}$ |
| 11.Knowing how to use statistics would boost my work possibilities | 541 | 1 | 5 | 3.10 | 1.00 | .03 | .09$^{*}$ | .04 |
| 12.When I face a statistics problem, I am unable to think clearly | 540 | 1 | 5 | 2.46 | 1.04 | -.11$^{**}$ | -.06 | -.01 |
| 13. I am calm and relaxed when faced with a statistics problem | 539 | 1 | 5 | 3.04 | 1.09 | .10$^{*}$ | -.08 | -.04 |
| 14.Statistics is enjoyable and stimulating for me | 540 | 1 | 5 | 2.17 | .98 | .15$^{**}$ | -.01 | .00 |
| 15.I hope I don't have to use statistics very often in my professional career | 541 | 1 | 5 | 3.29 | 1.08 | -.11$^{*}$ | -.09$^{*}$ | -.05 |
| 16.For professional development on our degree, I think there are more important subjects than statistics | 539 | 1 | 5 | 4.08 | .95 | -.15$^{**}$ | .04 | .04 |
| 17.Working with statistics makes me very stressed | 538 | 1 | 5 | 2.59 | 1.11 | -.07 | .01 | .01 |
| 18.I don't get stressed when I have to work on statistics problems | 538 | 1 | 5 | 3.01 | 1.11 | .09$^{*}$ | -.04 | .00 |
| 19.I would like to have an occupation in which I had to use statistics | 539 | 1 | 5 | 1.97 | .97 | .18$^{**}$ | -.01 | .04 |
| 20.I feel great satisfaction when I resolve statistics problems | 541 | 1 | 5 | 3.24 | 1.22 | .03 | .01 | .06 |
| 21.For professional development on my degree, one of the most important subjects should be statistics | 541 | 1 | 5 | 2.06 | .94 | .11$^{**}$ | .03 | .03 |
| 22.Statistics makes me feel uncomfortable and stressed | 539 | 1 | 5 | 2.55 | 1.08 | -.07 | .02 | .04 |
| 23.If I had to, I think I would be able to learn statistics well | 539 | 1 | 5 | 3.64 | 1.00 | .05 | .06 | .05 |
| 24.If I had the chance, I would enroll on more statistics courses beyond just the compulsory ones | 541 | 1 | 5 | 2.00 | .96 | .13$^{**}$ | .07 | .05 |
| 25.The material taught in statistics classes is not very interesting | 541 | 1 | 5 | 3.15 | 1.14 | -.15$^{**}$ | .00 | .01 |
| **CRITERIA** | **N** | **Min** | **Max** | **Mean** | **S** | **Rho1º** | **Rho2º** | **Rho3º** |
| 1.How would you value your current learning in dealing with statistical resources for research purposes? | 541 | 1 | 5 | 2.76 | .91 | 1.00 | -.03 | .08 |
| 2.Importance I attribute to being up to date through lectures, journal reading, attending seminars, congresses or training courses, etc. | 542 | 1 | 5 | 4.14 | .70 | -.03 | 1.00 | .29$^{**}$ |
| 3.Importance I attribute to distinguishing and teaching how to differentiate between what is true, what is likely true and what is false | 542 | 1 | 5 | 4.12 | .76 | .08 | .29$^{**}$ | 1.00 |

*Note*. Significant at < 0.05 (*) and at 0.01 (**)

### *Evidence of structural and convergent validity*

Given that the assumption of normality was not met (Table 4) following evaluation of the polychoric correlation matrix, robust estimators were applied (ULSMV) to the 11 examined models. These are described and summarized in Tables 5 and 6.

Table 4. Symmetry and multivariate kurtosis outcomes

| | **Statistical** | **P value** |
|---|---|---|
| Symmetry | 321382 | .000 |
| Kurtosis | 1327.736 | .000 |

Table 5. Construct dimensionality and the relationship of each item with its factor in the main five models

| **Item** | **Proposed Model** | **Auzmendi (1992)** | **Tejero & Castro (2011)** | **Méndez & Macía (2007)** | **Darías (2000)** |
|---|---|---|---|---|---|
| 1. | 1 | 1 | 3 | 3 | 4 |
| 6. | 1 | 1 | | 3 | 3 |
| 11. | 1 | 1 | | 3 | 3 |
| 20. | | 1 | | | 2 |
| 21. | 1 | 1 | | 1 | 3 |
| 24. | 1 | 4 | 2 | 1 | 3 |
| 2. | 2 | 2 | | 2 | 1 |
| 7. | 2 | 2 | 1 | 2 | 1 |
| 12. | 2 | 2 | 1 | 2 | 1 |
| 17. | 2 | 2 | | 2 | 1 |
| 22. | 2 | 2 | 1 | 2 | 1 |
| 3. | 3 | 3 | | 4 | 1 |
| 8. | 3 | 3 | | 4 | 1 |
| 13. | 3 | 3 | 1 | 4 | 1 |
| 18. | 3 | 3 | | 4 | 1 |
| 23. | 3 | 3 | | 3 | 4 |
| 4. | 4 | 4 | 2 | 1 | 2 |
| 9. | 4 | 4 | | 1 | 2 |
| 14. | 4 | 4 | 2 | 1 | 2 |
| 19. | 4 | 4 | 2 | 1 | 2 |
| 5. | 5 | 5 | 3 | 3 | 4 |
| 10. | 5 | 5 | 3 | 3 | 3 |
| 15. | 5 | 5 | | 2 | 4 |
| 16. | 5 | 5 | 3 | 3 | 2 |
| 25. | 5 | 5 | | 3 | |

Together with the models described in Table 5, a model developed by Auzmendi & Darias which included a second order factor was also examined. Furthermore, fit of the Auzmendi model was re-examined following removal of items 20 and 25. This was conducted given that removal of these items was supported in previous validations. Construct unidimensionality and factor orthogonality was assumed. Table 6 presents standardized indices in order to enable a comparative evaluation of the models.

Table 6. Fit indices of estimated models

| Model | χ2 | df | P | χ2 /df | RMSEA | 90% CI | | CFI | TLI |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | LL | UL | | |
| **1) Proposed model** | **775.242** | **237** | **.000** | **3.271** | **.066** | **.061** | **.071** | **.923** | **.911** |
| 2) Auzmendi (1992) | 1099.4 | 265 | .000 | **4.149** | **.078** | .073 | .083 | .882 | .867 |
| 3) Darias (2000) | 1145.802 | 246 | .000 | **4.658** | .084 | .079 | .189 | .871 | .856 |
| 4) Méndez and Macía (2007) | 1615.261 | 246 | .000 | 6.566 | .103 | .099 | .108 | .809 | .786 |
| 5) Tejero and Castro (2011) | 373.74 | 51 | .000 | 7.328 | .109 | .099 | .12 | .892 | .86 |
| 6) 3 with a second order factor | 2524.152 | 249 | .000 | **1137** | .133 | .128 | .137 | .675 | .640 |
| 7) 2 without item 20 | 1022.752 | 244 | .000 | 4.192 | **.079** | .074 | .084 | .891 | .876 |
| 8) 2 without item 25 | 2238.191 | 244 | .000 | 9.173 | .125 | .121 | .13 | .715 | .678 |
| 9) 2 unidimensional | 2858.598 | 275 | .000 | **1395** | .134 | .13 | .139 | .635 | .602 |
| 10) 2 with a second order factor | 279586 | 271 | .000 | **1297** | .134 | .129 | .138 | .644 | .601 |
| 11) 2 without correlations | 5108.575 | 275 | .000 | 18.577 | .184 | .179 | .188 | .318 | .256 |

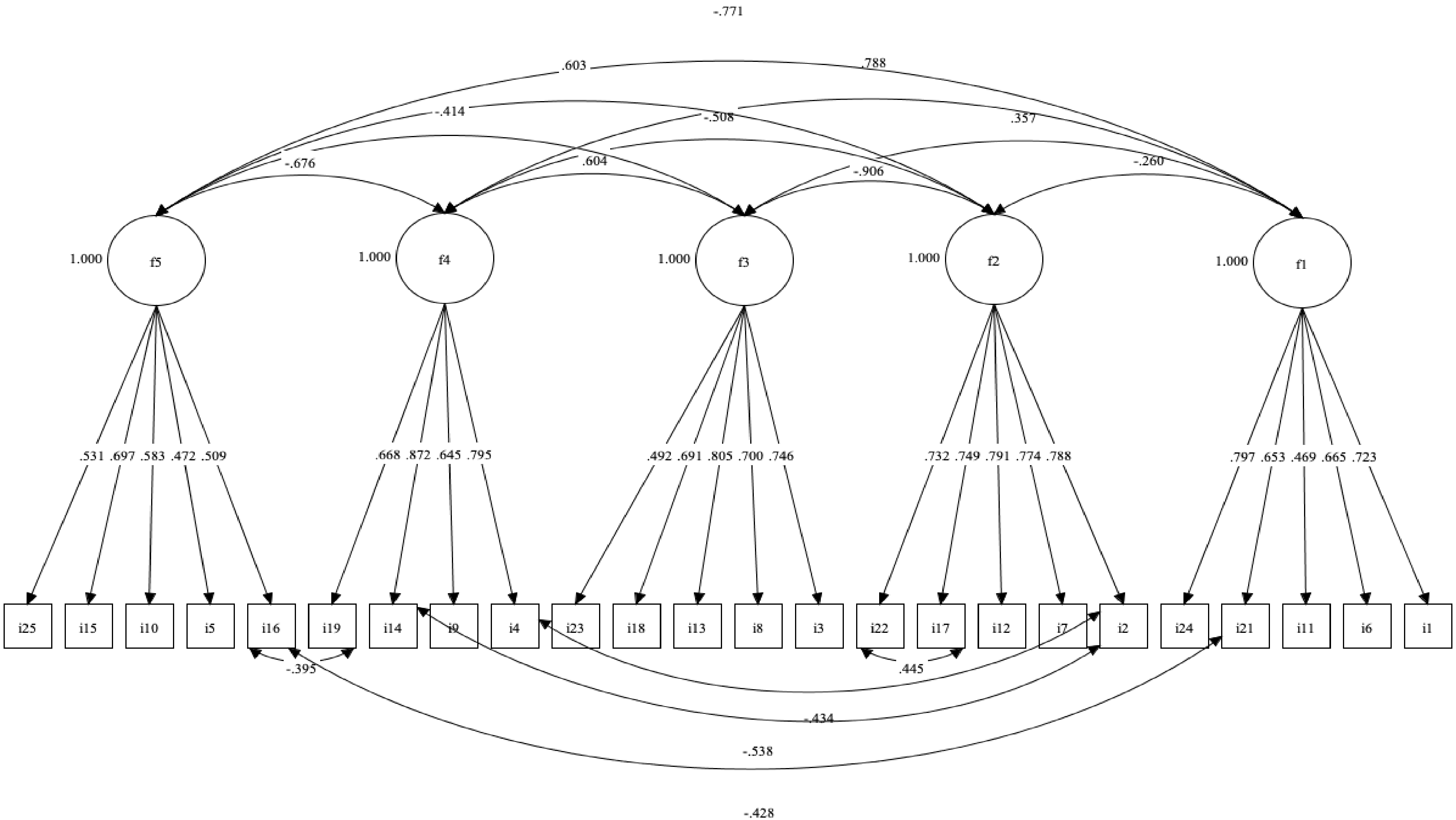
The original model conceived by Auzmendi (2) showed the best fit, with better fit than a comparative unidimensional model (9). Neither model 10, which included a general second-order factor, nor model 7 or 8, which removed items 20 and 25, respectively, managed to improve on the outcomes produced by the original model. Model 11, which estimated non-correlated factors, for instance via a varimax solution, achieved the poorest fit. Models proposed in previous studies, when examined using the present method and sample, also failed to achieve acceptable fit indices. The model that was most statistically aligned to the original was that described by Darias (2000). However, the organization of items and factors in their study deviated from Auzmendi's theoretical proposal. The proposed model (Figure 1) is organizationally very similar to the original. It achieved best fit when considering modification indices with theoretical significance, which, subsequently, led to moving item 24 from the pleasure factor (F4) to usefulness (F1), eliminating item 20, and correlating the residuals produced between items 2 and 14, 2 and 4, 16 and 21, 17 and 22, 16 and 19.

Convergent validity was also examined (Table 7) in the proposed model. With regards to AVE, four factors obtained values close to .5. In the final dimension alone, larger average error terms were found for the separate items explained by the latent factor. On the whole, the model managed to explain 48% of variance in the data. The reliability coefficients indicate suitable convergent validity, except in the case of F5, where outcomes are only marginally acceptable.

Table 7. Reliability and convergent validity according to AVE

| Factor | AVE | Composite reliability | Cronbach's ordinal alpha |
|---|---|---|---|
| F1(Usefulness) | .450 | .799 | .803 |
| F2(Stress) | .588 | .877 | .889 |
| F3(Confidence) | .483 | .820 | .82 |
| F4(Pleasure) | .564 | .836 | .842 |
| F5(Demotivation) | .318 | .696 | .702 |

Figure 1. Proposed model with loadings and correlations between errors



With regards to the shared variance between items and factors (Table 8), the items which are best represented in the proposed measurement model are items 14, 13 and 24, whilst the least represented are items 11 and 5, $R^2$ being significant in all cases.

Table 8. Relationship between latent and observed variables

| Factor | Item | $R^2$ | Loading | SE | P value |
|---|---|---|---|---|---|
| 1 | 1 | .523 | .723 | .031 | .000 |
| 1 | 6 | .443 | .666 | .029 | .000 |
| 1 | 11 | .22 | .469 | .037 | .000 |
| 1 | 21 | .426 | .653 | .036 | .000 |
| 1 | 24 | .636 | .797 | .027 | .000 |
| 2 | 2 | .621 | .788 | .022 | .000 |
| 2 | 7 | .599 | .774 | .023 | .000 |
| 2 | 12 | .625 | .791 | .019 | .000 |
| 2 | 17 | .56 | .748 | .024 | .000 |
| 2 | 22 | .536 | .732 | .024 | .000 |
| 3 | 3 | .557 | .746 | .027 | .000 |
| 3 | 8 | .49 | .700 | .026 | .000 |
| 3 | 13 | .648 | .805 | .02 | .000 |
| 3 | 18 | .477 | .691 | .027 | .000 |
| 3 | 23 | .242 | .492 | .035 | .000 |
| 4 | 4 | .633 | .796 | .025 | .000 |
| 4 | 9 | .416 | .645 | .033 | .000 |
| 4 | 14 | .761 | .872 | .02 | .000 |
| 4 | 19 | .447 | .669 | .03 | .000 |
| 5 | 5 | .223 | .472 | .036 | .000 |
| 5 | 10 | .34 | .583 | .042 | .000 |
| 5 | 15 | .485 | .696 | .035 | .000 |
| 5 | 16 | .259 | .509 | .036 | .000 |
| 5 | 25 | .282 | .531 | .039 | .000 |

Finally, significant correlations were obtained between all factors (Table 9), being greater that .25 in all cases. The factors of usefulness (F1) and stress (F2) were the least strongly related. As expected, usefulness was strongly and positively correlated with pleasure (F4) and strongly and negatively correlated with demotivation (F5). The strongest correlation was produced between stress (F2) and confidence (F3), with this relationship being inverse.

Table 9. Correlations between factors

| | Correlation | SE | P Value |
|---|---|---|---|
| F1-F2 | -.26 | .045 | .000 |
| F1-F3 | .357 | .044 | .000 |
| F1-F4 | .788 | .024 | .000 |
| F1-F5 | -.771 | .029 | .000 |
| **F2-F3** | **-.906** | **.015** | **.000** |
| F2-F4 | -.508 | .036 | .000 |
| F2-F5 | .603 | .038 | .000 |
| F3-F4 | .604 | .034 | .000 |
| F3-F5 | -.414 | .049 | .000 |
| F4-F5 | -.676 | .032 | .000 |

### *Evidence of the predictive value of EAE items*

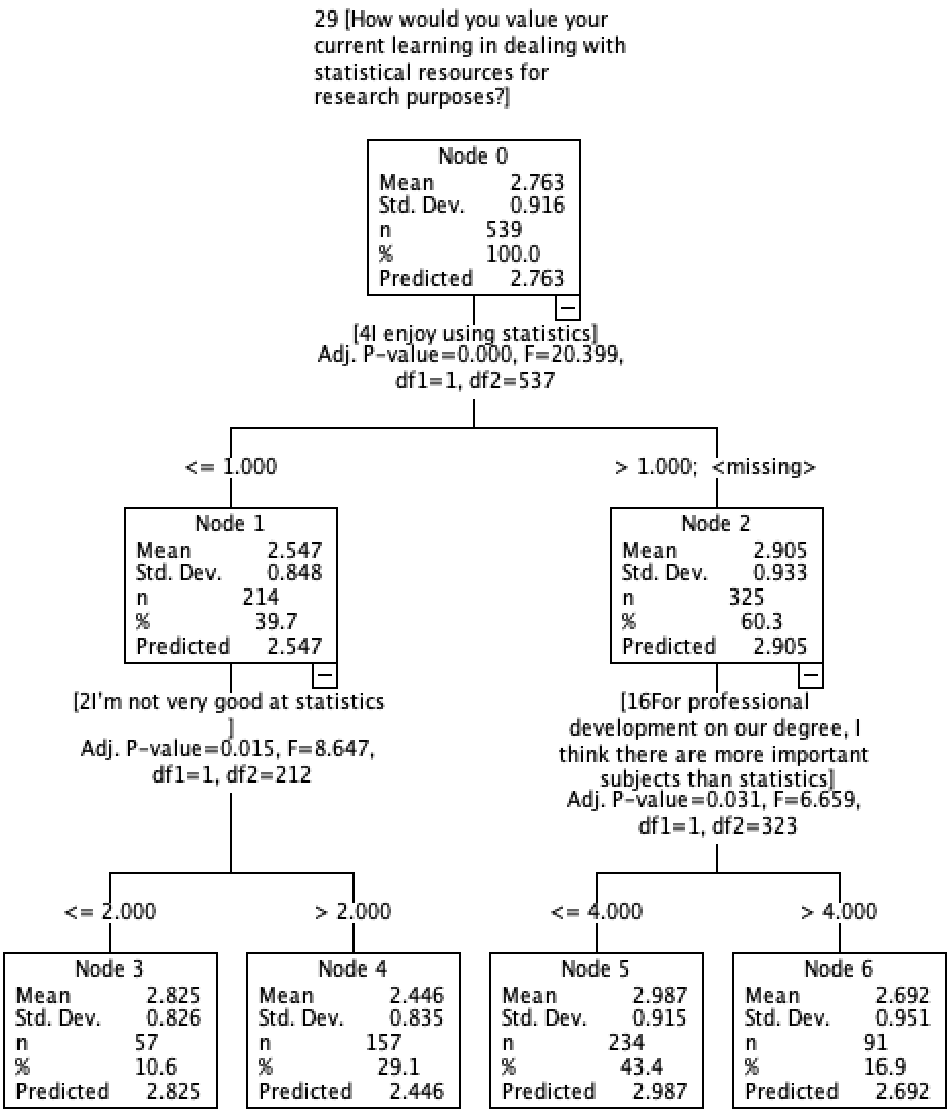
Validity indices were produced by conducting bivariate correlations between the items and the criteria. Specifically, Spearman correlations were conducted. Outcomes are presented in the last three columns of Table 3. Multivariate regression trees adjusted for ordinal data were developed. The 25 items included on the Auzmendi scale (1992) were included in the model as predictors and criteria. Three (CHAID) trees were produced, which are presented below (similar to those produced via CART).

First, the relationship is examined between attitudes towards statistics and self-perceptions of competence in this subject (criteria 1) as an indicator of performance with regards to the use of statistics in research (1=very poor; 2=poor; 3=adequate; 4=good; 5=excellent). Figure 2 shows (node 0) that the 539 respondents reported average criteria scores of 2.763, associated with a standard deviation of .916. This means that, as a group, participants did not consider their statistics skills to be sufficient. One of the EAE items to best discriminate outcomes for this variable pertained to item 4 (F4 pleasure), with response option 1 ‘not at all fun’ marking the cut-point and giving rise to nodes 1 and 2. Significantly different outcomes were produced in this group relative to those not giving this response (2.547 vs. 2.905; P=.0).

Another determinant was item 2 (F2 stress), with those totally disagreeing or disagreeing that they experienced stress producing different outcomes to the rest of the sample. This gave rise to nodes 3 and 4, with mean differences again being statistically significant (P=.015). Finally, item 16 pertaining to demotivation (F5) emerged as determinant, with individuals reporting that they totally agreed being differentiated from the rest. This gave rise to nodes 5 and 6, with mean differences again being significant (2.987 vs. 2.592; P= .031). A total of 157 participants reported perceiving themselves to have low ability and so were assigned to node 4 (students who agreed, strongly agreed or totally disagreed that they are poor at statistics and reported not enjoying it at all).

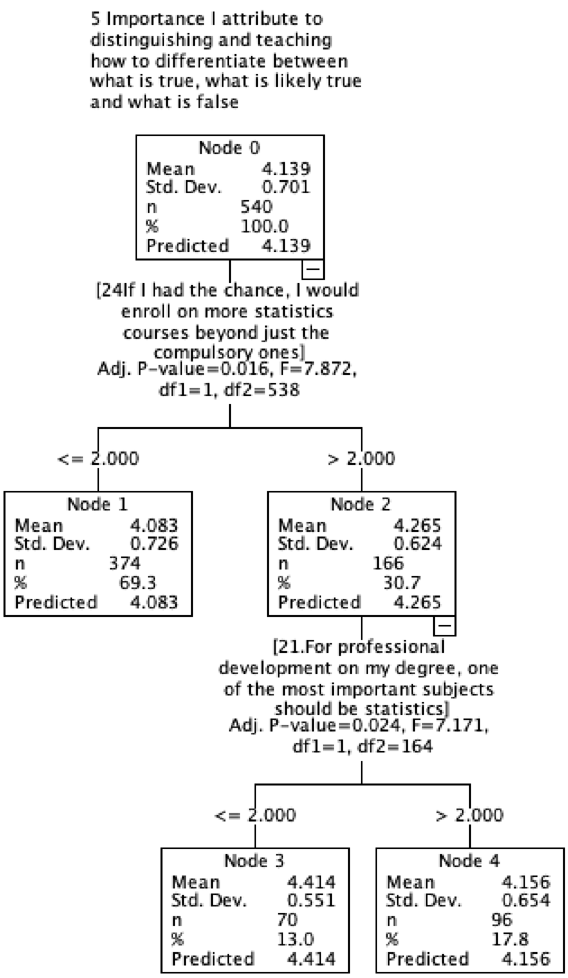
EAE items were ranked according to their importance in accordance with CART-based criteria: 16, 4, 25, 2, 19, 1, 9, 14, 24, 21, 7, 12, 15, 6, 8, 17, 13, 20, 11, 18, 22, 10 and, finally, 23. Neither 3 nor 5 emerged as being important.

Figure 2. Regression tree for the "self-assessment of statistics handling" variable



The usefulness of EAE items was also explored for discriminating between teaching degree students as function of the importance they attributed to being up to date through reading journals, attending conferences, etc. This variable was employed as criteria 2 (Figure 3).

Figure 3. Regression tree for the "importance of being up to date" variable




In general, consulted students attributed quite a lot of importance to this issue (mean= 4.139), with attributions being even higher amongst those reporting that they would study statistics more if that were possible, although they did not consider it to be the most important subject on the course (node 3). In this case, the most discriminative items were items 24 (cut-point determined between response options 1 and 2) and 21 (cut-point determined between response options 2 and 3), both of with corresponded to the usefulness factor (F1) in the proposed model. The students who attributed less importance to being up to date are found in node 1. A total of 22 items were included in the CART normalized importance table, with items 10, 11 and 20 being deemed not to be important.

Finally, criteria 3 was examined, pertaining to the usefulness of EAE items for discriminating between respondents as a function of the importance they attribute to teaching certain types of content (Figure 4). In general, all those surveyed deemed it important to be able to determine between that which is true and that which is false (mean = 4.126), with higher scores amongst those who totally or strongly agreed that statistics is important (node 2). Item 1, corresponding to the usefulness factor (F1), gave rise to two nodes with significant differences in the DV (P=.005) between those reporting scores higher than 3 and those not. Although not included in the final tree diagram, CART also determined items 24, 14, 4 and 6, corresponding to the usefulness and pleasure factors (Figure 5), to be important. A total of 20 EAE items were found not to be relevant to these criteria.

Figure 4. Regression tree for the "importance of teaching how to discriminate between what is true and false" variable

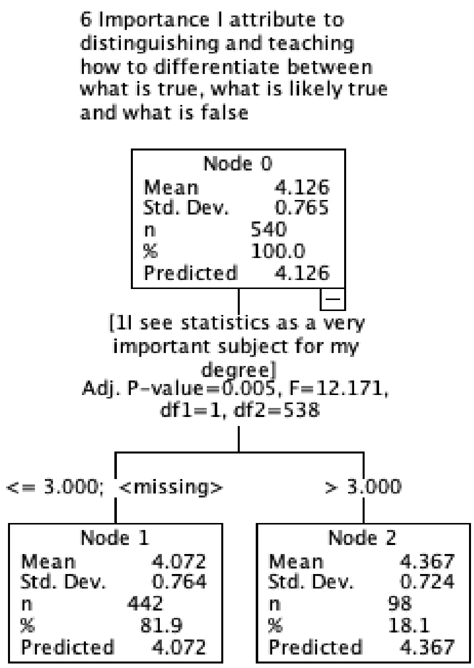
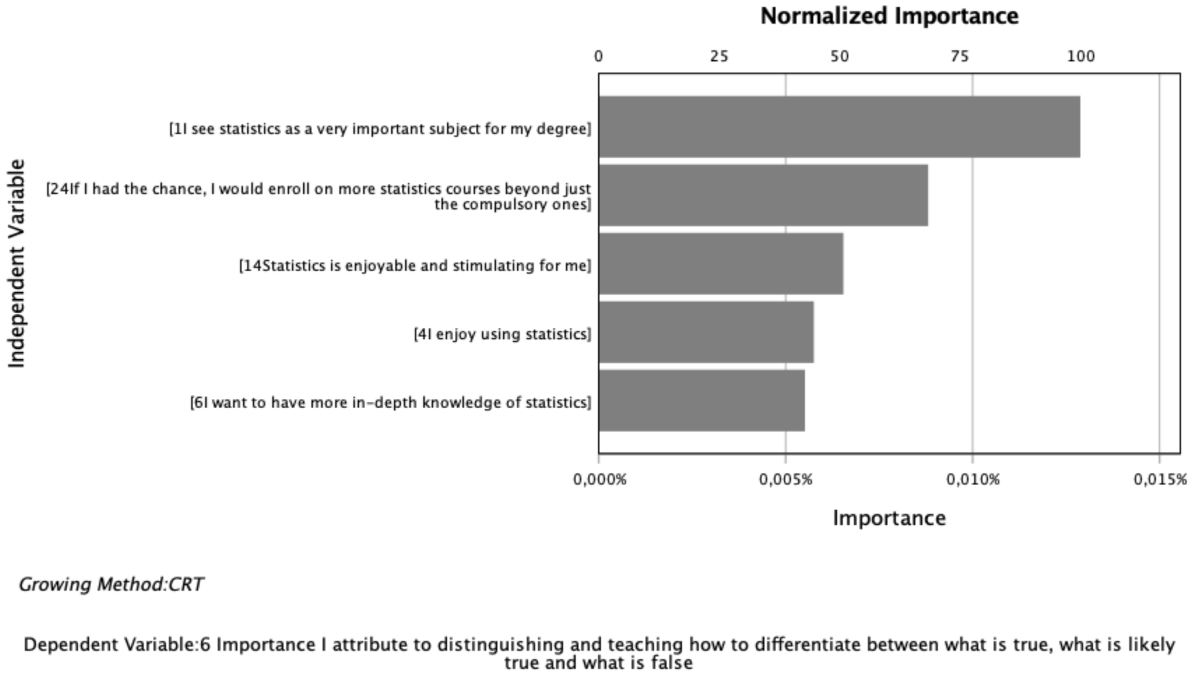


Figure 5. Graph of the importance of the predictors




## Discussion and conclusions

Present findings support the conclusion that future teachers do not hold very positive attitudes towards statistics, considering it to not be very useful or pleasurable. Despite this, it does not provoke stress, with future teachers feeling confident and reasonably motivated to tackle it. Furthermore, it was revealed that participants perceive themselves unable to cope adequately with statistics to be able to perform research, although they were interested in being up to date and able to discriminate between fact and fiction.

With regards to the first objective, the factor structure of the EAE outlined by Auzmendi (1992), comprising 25 items and 5 factors, obtained acceptable fit, except with regards to comparative indices. The model was improved by removing item 20, changing the dimension of 24 and correlating a number of error terms. Such modifications are appropriate for meeting empirical criteria, whilst also considering theoretical tenants. Removal of item 20 was supported by validity indices and regression tree outcomes as the item was not relevant to any criteria. Further, reliability and convergent validity indicators suggested that the proposed model was reliable. The other examined models did produce satisfactory outcomes when applied to the present method and sample. Darias' model (2000), which reduces the number of dimensions to four, produced an overall fit index which could be considered acceptable. However, structural modifications were required which deviated theoretically from the original proposal and produced a high RMSEA. Tejero & Castro's (2011) model produced an overall fit index ($Chi^2$/df) higher than 5 and a high RMSEA value, although the CFI and TLI were similar to those obtained in the Auzmendi model (1992) and 59% of variance was explained. With regards to the proposal made by Méndez & Macía (2007), 74% of total variance was explained, with this being greater than that reported by the original authors. However, neither the $Chi^2$ coefficient/df nor the incremental fit index achieved acceptable values.

As for the second objective, centered on examination of the usefulness of the EAE for making training decisions, it can be concluded that attitudes towards statistics are linked to personal performance assessments in this subject. According the multivariate analysis performed, the most important items were items 2, 4 and 16, showing that factors pertaining to stress, pleasure and motivation have the biggest influence on this relationship. With regards to the relationship between attitudes and interest in critical and reflective thinking (Betancur et al., 2012) and being up to date (for which statistics provides the necessary language [Gaviria, 2015]), the most relevant items were items 1, 21 and 24, with these corresponding to the usefulness dimension. These findings suggest that the scale provides relevant indicators of the importance attributed by future teachers to science and research in their field. On this matter, it is worth highlighting the use of regression trees as a novel methodological tool. This tool complements more commonly used metric approaches based on construct dimensionality, providing additional diagnostic information and predictive data on the usefulness of measurements (Álvarez Benítez & Asensio-Muñoz, 2020; Blanco et al., 2017).

With regards to limitations, it should be stated that the non-probabilistic approach taken to sampling means that findings cannot be generalized to the wider teaching degree student population. Furthermore, although fit indices for the proposed model were acceptable and comparable with those obtained by Rodríguez Santero & Gil Robles (2019) for the SATS-36, the model only manages to explain 48% of variance in the data and fit could be improved. Attention should also be drawn to the high correlation found between stress (F2) and confidence (F3) which, with a value of -.9, could indicate that two ends of the same spectrum are being measured. As argued by Darias (2000), these may be better considered as one single factor denominated security. Finally, with regards to the analysis of predictive validity, simple and highly inferred items were used as criteria but, in order to obtain more reliable evidence, it would be useful to collect objective performance data, alongside more reliable measures of interest in being up to date and scientific evidence. Such an approach may require the use of longitudinal designs.

Despite the discussed limitations, the present study has interesting implications. It provides evidence that the tool applied to evaluate attitudes of future teachers towards statistics is valid. Further, this tool could be applied to examine the relationship between teachers' attitudes and children's interest in science. This is particularly relevant given that the teaching of STEM subjects (science, technology, engineering and mathematics) is a priority. This was achieved using a robust non-parametric methodology (Lloret-Segura et al., 2014) and adequate multivariate techniques for ordinal data.

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**Authors / Autores**

**Navarro-Asencio, Enrique** (enriquen@ucm.es) 0000-0002-3052-146X

Phd in education (with extraordinary award) from from the Complutense University of Madrid (UCM). He was Assistant Professor at the International University of La Rioja (UNIR) from 2012 to 2015. He is currently Full Professor at UCM and member of the research group in "Measurement and Evaluation of Educational Systems". His line of research is related to educational measurement and evaluation of academic performance and associated factors.

**Asensio-Muñoz, Inmaculada** (macu@edu.ucm.es) 0000-0003-3523-570X

Doctor in Philosophy and Educational Sciences (UCM) with an extraordinary award, Professor in the Department of Research and Psychology in Education of the Faculty of Education and member of the UCM Consolidated Research Group “Measurement and Evaluation of Educational Systems”. Her main lines of work are educational research and evaluation methodology.

**Arroyo-Resino, Delia** (delia.arroyo@unir.net) 0000-0002-3784-7745

Lecturer of the Department of Research Methods and Diagnosis in Education at the International University of La Rioja (Spain). She is a research member in the University Group of "Measurement and Evaluation of Educational Systems" (Complutense University of Madrid). Her main research interests are research methodology, data analysis in education and psychometrics.

**Ruiz-De Miguel, Covadonga** (covaruiz@edu.ucm.es) 0000-0002-6941-5402

Doctor in Philosophy and Educational Sciences (UCM). Professor in the Department of Research and Psychology in Education of the Faculty of Education and member of the UCM Consolidated Research Group “Measurement and Evaluation of Educational Systems”. Her main lines of work are research methodology and data analysis.

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