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An Integrative Model for the Study of Attitudes Towards Statistics, Part 1: Establishing the Conceptual Model

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Abstract: We propose a model to study attitudes towards statistics in higher education teachers. In the literature, there is a host of scientific articles aimed at developing and applying measurement instruments whose psychometric characteristics are generally statistically acceptable. However, publications on the structure of attitudes and their relationship with teaching are relatively scarce-especially those dedicated to statistics in higher education. Based on the system of attitudes proposed by Ajzen and Fishbein, the objective is to develop a model to put into perspective what happens to teachers in the classrooms of higher education institutions. It is imperative to know teachers' attitudes and make the appropriate modifications considering the digitalization of information and increased databases.

Keywords: Attitude, Statistics, Teaching, Academic Instrument, Higher Education

Introduction

State of the Art

Hassad and Coxon (2007) point out that the reform movement for change in the teaching of statistics in the United States has lasted more than a decade and that during that time, they have moved from the traditional mathematical approach to the constructivist approach. However, the results continue to be nimble since there is evidence of a lack of understanding of basic concepts such as the graphical representation of distributions, randomness, and sampling. These modifications to the change in teaching are due to the teachers' experience and beliefs about education. With this background, the authors developed and validated a scale to measure instructors' attitudes towards teaching based on concepts of introductory statistics in health and behavioral sciences, called Faculty Attitudes Towards Statistics (FATS). However, the psychometric values are inconclusive; the researchers point out that they may help make decisions regarding teaching statistics and reforming education.

On the other hand, (Hannigan *et al*., 2013) reported an investigation on the conceptual knowledge and attitudes toward statistics of prospective mathematics teachers at the secondary level. They mention that mathematics teachers recognize the practical importance of statistics and are willing to give preponderance to statistics teaching. They found that mathematics teachers consider that they are not prepared for teaching statistics. The evidence is that statistical thinking is different from mathematical thinking and that a strong background in mathematics does not necessarily translate into statistical thinking. The finding indicates favorable attitudes and the recognition that statistics is not an area where everyone learns quickly and requires discipline. They recommend teacher training programs in statistics, highlighting mathematical and statistical thinking differences.

More recently, Estrada *et al*. (2013) recognized that statistics courses are not mandatory in large part of the curricula. In other cases, the subject is reduced, eliminated, or taught with inadequate methodologies, which leads to poor preparation. Their training is limited, so the teacher cannot acquire teaching practice in teaching statistics.

The authors evaluated the psychometric properties of a scale of attitudes towards statistics in 288 practicing and trainee teachers in Spain and Peru. For this purpose, they used an instrument created specifically by Estrada (2002), who in turn combined three questionnaires to develop it: Statistics Attitudes Survey (SAS Scale) by Roberts and Bilderback (1980); Attitude Towards Statistics (ATS Scale), by Wise (1985) and that of Auzmendi Escribano (1992). The

results indicate that the psychometric performance is inadequate.

Marshman *et al*. (2015) published a case study of mathematics teachers' attitudes toward statistics in Queensland, Australia. The authors note that the new mathematics curricula added more statistics courses, content, and hours.

With this background, a 21-item questionnaire was administered to a sample of 40 teachers at a meeting of math teachers. The purpose of the survey was to provide a picture of practicing teachers' attitudes toward statistics measured in four domains:

- Cognitive: Attitudes about knowledge and skills applied to statistics
- Technology: Attitudes toward learning statistics with technology are interpreted broadly to include computers and graphing calculators
- Value: Attitudes towards the importance and usefulness of statistics in personal and professional life
- Affective: Emotions associated with statistics

In addition, the authors conducted focus groups and interviews with professors with long teaching careers.

The results indicate that the affective domain has a more excellent dispersion of scores, meaning a broader range of emotions attached to statistics. In addition, teachers who reported better skills are more likely to write a positive attitude toward statistics.

Regarding the interviews, the participants pointed out that training in statistics is insufficient and has been underutilized for many years. Another mathematics teacher nearing retirement highlighted the urgent need to prepare people to teach statistics.

As Marshman *et al*. (2015) stated, although teachers value the importance of statistics and appreciate the use of technology as a support, they feel unprepared and less competent to teach it. For this reason, the support network for mathematics teachers in the sunshine coast region of Queensland sees this as a window of opportunity to close gaps in understanding and approaching statistical pedagogy.

In South America, (Oliveira, 2016), reported a study that aimed to validate a scale of attitudes for teachers who teach Statistics in Higher Education in Brazil. They worked with a sample of 334 Brazilian teachers from all regions of Brazil who taught statistics disciplines in different areas of knowledge (exact sciences, health, and humanities) in public and private higher education institutions. The author points out the need to identify the attitudes of teachers who teach statistics because this knowledge could contribute to planning and delimit specific, assertive, and adequate actions for teaching and, at the same time, take into consideration the affective aspects of the teacher about statistics.

Oliveira (2016) reviews the literature and acknowledges the work of Carmona (2004) on ten instruments for measuring attitudes towards statistics. She also analyzes the methodology from Estrada *et al*. (2013; cited in Oliveira, 2016) for comparing attitudes towards statistics in teachers from Peru and Spain.

It also highlights his previous research; (Oliveira and Morais, 2009) as one of the first Brazilian attempts to measure positive attitudes towards Statistics Teaching through a Likert-type instrument. Later, (Oliveira, 2011), with the evaluation of attitudes, personal characteristics, the use of technologies, and teaching practices of statistics teachers at the Catholic University of Brasilia developed a method to help in the teaching-learning process of Statistics. Oliveira (2016) considered the affective, cognitive, behavioral, and anthropological components: Social, educational and instrumental. The results showed six factors or dimensions: Appreciation, affectivity, teaching, content, methodological-instrumental, and abstraction:

- Appreciation: Consider the multidisciplinary nature of statistics and the cultural and social context
- Affectivity: Reflect on the emotions and feelings that statistics arouse in teachers, for example, rejection of interest
- Teaching: The teacher's interest in teaching statistics allows them to adapt strategies, propose investigations with theoretical-practical activities for their students and use their experience and mastery
- Content: To stimulate learning basic concepts in teaching statistics by integrating new knowledge with previously known content
- Methodological-Instrumental: The rigor required by the teacher in teaching statistics encourages the linking of statistical methods with scientific techniques, also seeking logical explanations as a way of thinking about statistics
- Abstraction: The teacher considers necessary the mathematical conception of his students to achieve the teaching of statistics

The findings highlight the inclusion of characteristics such as the stimulation of the basic concepts of statistics, the methodological rigor demanded, and the mathematical abstraction required by the teacher. These conditions are indispensable to determining a positive attitude toward the teaching of statistics.

On the other hand, Kim *et al*. (2019) published an article on attitudes toward the use and teaching of confidence intervals. They sought to analyze the profiles of primary university statistics teachers. For this purpose, they applied a measurement instrument to 270 participants. The researchers pre-established the affective, cognitive, and behavioral components and created three profiles: Stable score group, high score group, and diverse score

group, based on their attitudes towards Confidence Intervals (CI), as a testing process the null hypotheses.

The initiative arose because the literature review found that, in the pedagogical context of elementary university statistics, more learning could be achieved by using CIs instead of the null hypothesis significance test with the p-value.

The results indicate differences in how university teachers develop attitudes towards using and teaching confidence intervals. These variables are gender, academic background (graduate degree in mathematics, no graduate degree in statistics; having a graduate degree in statistics; having a graduate degree in mathematics and a graduate degree in statistics), statistical teaching experience, subject preference (mathematics or statistics), academic degree and desire to improve teaching.

They recommend that university professors of introductory or elementary statistics use confidence intervals more frequently.

In Peru, Martínez and Oliva (2021) developed a virtual course to improve teachers' attitudes toward statistics in a private university in Peru. They proposed two dimensions to study attitudes toward statistics. The pedagogical dimension includes three components: Affective, cognitive, and behavioral. Whereas the anthropological integrates three parts: Social, educational, and instrumental. The results indicate that the pretest measurement had neutral attitudes. In contrast, in the posttest, the attitudes were highly positive, thus proving the advantages of the course. The cognitive component (pedagogical dimension) and the social component (anthropological dimension) showed better scores.

Finally, Monteiro and Carvalho (2021), focus on knowledge and technical procedures of curricular content in statistics and attitudes. The study addresses the challenges of teaching statistics in Brazil. The study provides empirical evidence that an effective pedagogical strategy to improve teachers' knowledge of statistics is to explore dialogue in which students can be led to reflect on their interpretations of statistical data related to contemporary contexts involving different topics. The work developed by GPEME also allowed them to value the social and cultural contexts and local knowledge, which is why they consider it necessary to rethink the theoretical and methodological position on statistics education. They further reflected on the development of tasks and activities related to statistical issues in teacher training, which is more explicitly linked to the socio-cultural conditions of students.

The discussion also noted the need for educational software to teach statistics that could favor motivation in both directions, teachers, and students. They also agreed with the recognition that teachers should base the data interpretation process on an active and participatory perspective, involving teachers in developing more innovative methodologies.

One of the strategies that have been successful in Brazil is to pose questions to the teachers who attend the meetings and workshops for training and pedagogical updating. They found that asking questions promotes reflection on concepts of probability and statistics, adopting a critical approach when rethinking the teaching of these concepts.

In addition, some aspects of the so-called creative insubordination in the training of mathematics education teachers understood as an alternative to traditional teaching through critical thinking were reviewed. They point out that the creatively insubordinate teacher needs to make decisions constantly. In most cases, this requires assuming positions and creating new work dynamics that oppose the established professional routine or administrative guidelines. From this perspective, teachers should not only limit and challenge their practice to previously determined objectives but also consider their students' socio-historical and cultural contexts.

Several challenges remain to be addressed in Brazil, such as the lack of continuing education to update and expand the knowledge of teachers in rural regions; the need for teacher feedback as a promoter of the active processes of teaching and learning in statistics; new approaches in the educational context caused by the COVID-19 pandemic; social practices influenced by global phenomena. They conclude that it is essential to continue researching to achieve a greater understanding and development with a critical stance on statistics, both in teachers and in their students, promoting more effective citizen participation.

The study's objective is to propose a model of attitudes of higher education teachers towards statistics, which seeks to integrate some additional considerations to the cognitive, affective, and behavioral dimensions, in which other components and indicators intervene.

Materials and Methods

It is a non-experimental study. A conceptual model of attitudes towards statistics for higher education teachers is established and will allow specialists to have an updated theoretical-methodological structure for their study, integrating some additional aspects to conventional models.

The structure of Ajzen and Fishbein's attitudes was also used as background, and a Likert-type scale measurement instrument was reviewed and analyzed to contextualize.

Model

Ajzen Model

To define the multidimensional construct of attitudes toward statistics, it is necessary to analyze the work of Allport (1935), Fishbein and Ajzen (1977), Ajzen (1989; 1991), and Rodrigues *et al*. (2015). The structure of attitudes, therefore, is composed of three dimensions:

- Cognitive: It represents knowledge, belief, or structured perception about a given social object (in this case, statistics)
- Affective: Instilled in the emotions and feelings presented in two variants contrary to each other, it allows to value in favor or against a given social object (in this case, statistics)
- Behavioral: It is the behavior, conduction, or predisposition to act congruently with the cognition and affection towards said social object (in this case, towards statistics)

This classic model of attitudes evolved with the theory of reasoned action and the theory of planned behavior. Ajzen and Fishbein (1980) describe moments in which the person is forced to evaluate the possible implications of their actions or their actions. This requirement leads to a logical sequence that results in the intentionality of their behavior. They ratify attitudes' importance, measurement power, permanence in time, and predictive capacity.

Proposed Model

Ajzen (1991) points out that we learn to favor behaviors that we believe have desirable consequences and reject behaviors that we associate with undesirable effects. Thus, the subjective value of the outcome contributes to the mood in direct proportion to the strength of the belief, i.e., the subjective probability that the behavior will produce the product in question, as shown in Eq. 1:

$$A\alpha \sum_{i=1}^{n} b_i e_i \quad (1)$$

A = Attitude of a person
b = The strength of each belief
e = Subjective evaluation

The strength of each salient belief (b) is combined in a multiplicative manner with the subjective evaluation (e) of the attribute beliefs and the resulting products are summed over the n salient beliefs. A person's attitude (A) is directly proportional ($\propto$) to this summative index of trust (Ajzen, 1991, page 191). Ajzen also develops other relations. For instance, to estimate parameters of normative beliefs and subjective norms.

In another vein, Gal (2002), based on the work of Ajzen and Fishbein (1980), proposes a structure for statistical literacy to explain two elements: Knowledge (through literacy skills, statistical knowledge, mathematical knowledge, knowledge of the context, and critical questions); and disposition (beliefs, attitudes, and critical stance).

Later, Estrada *et al*. (2013) use Fishbein and Ajzen's (1977) dimensions of attitudes and call them pedagogical. And at the same time, they add another aspect to which they assign the name anthropological, which includes three elements: Social, educational, and instrumental.

We propose a model for the attitudes of higher education teachers towards statistics that consists of a structure of attitudes made up of three dimensions: Cognitive (Beliefs and Knowledge), Affective Assessment (Favorable and Unfavorable), and Behavioral (Predisposition to act, evaluation of the implications and intentionality of the behavior). A diagram showing the model based on a structure of attitudes is presented in Fig. 1. The model and its corresponding dimensions are shown graphically in Fig. 2. Teaching statistics at the university require that the teacher collect the proposed skills.

From the diagram, a model can be generated based on the attitudes of higher education teachers towards statistics, as shown in Table 1. The model considers attitudes. The structure contemplates relevant aspects such as subjective beliefs, knowledge of the context, a critical stance, perception of control, predisposition to act, evaluation of the implications, and intentionality of the behavior. The model is summarized in Table 1.

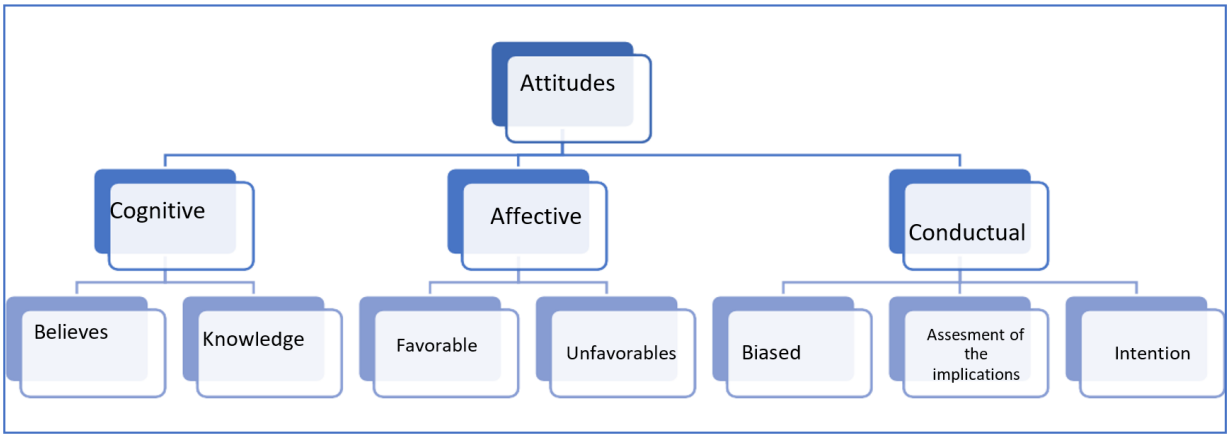

Fig. 1: Proposed structure of attitudes

Table 1: Model for the study of higher education teachers' attitudes towards statistics

	Dimensions	Components	Indicators	In the face of statistics
Attitudes		Beliefs	Regulations	Need for courses, curricular units,or subjects in statistics
			Subjective	• The difficulty of statistics • Teaching experience
			Informative	• The usefulness of statistics • Application of statistics
	Cognitive		Knowledge, understanding and mastery	• Descriptive statistics • Inferential statistics • Probability
		Knowledge	Pedagogical knowledge	• Didactics of teaching young adults • Classroom communication • Technology (software, platforms, etc.)
			Knowledge of the context.	• Socio-cultural aspects of the higher education institution, the degree program, its students, the students • Themselves and the teaching modality (virtual vs. face-to-face, etc.)
			Critical stance.	• Reflections on teaching statistics in higher education.
	Affective	Favorable	Positive emotions	• Joy
			Motivation	• Challenges of statistical education in higher education
			Perception of control	• Importance of Statistics • Sense of security
		Unfavorable	Negative emotions	• Wrath • Sadness • Fear
			Negative feelings	• Discomfort due to the unknown • Threat sensation • The feeling of lack of support
			Anxiety	• Nervousness • Concern • Apprehension
			Disability	• Lack of pedagogical preparation of teachers in statistics • Lack of preparation in statistics
	Conductual		Willingness	Favorable • Develops the curricular unit, course, or subject syllabus • Complies with the institutional provisions for teaching the to act statistics course • Update your program
			Unfavorable	• Dissatisfied with the institution • Dissatisfied with life • Dissatisfied with himself
		Evaluation of the implications	Desirable and consequences	• Alternatives to traditional teaching • Integrate statistics with empirical research • Use quantitative methods • Teaching statistics for daily life • Teaching statistics for professional or working life.
			Undesirable consequences	• Teaching in the traditional way
		Intentionality of behavior	Avoidance	• He prefers not to teach statistics
			Escape reagent	• Focuses on mathematics rather than statistics
			Attack reaction	• Decision-making on the flexibility of teaching strategies • Statistical practice • Use of technology • Resources and activities according to the context and individual and group needs • Data management • Conduct experiments • Feedback on their teaching practice with their students • Upgrades

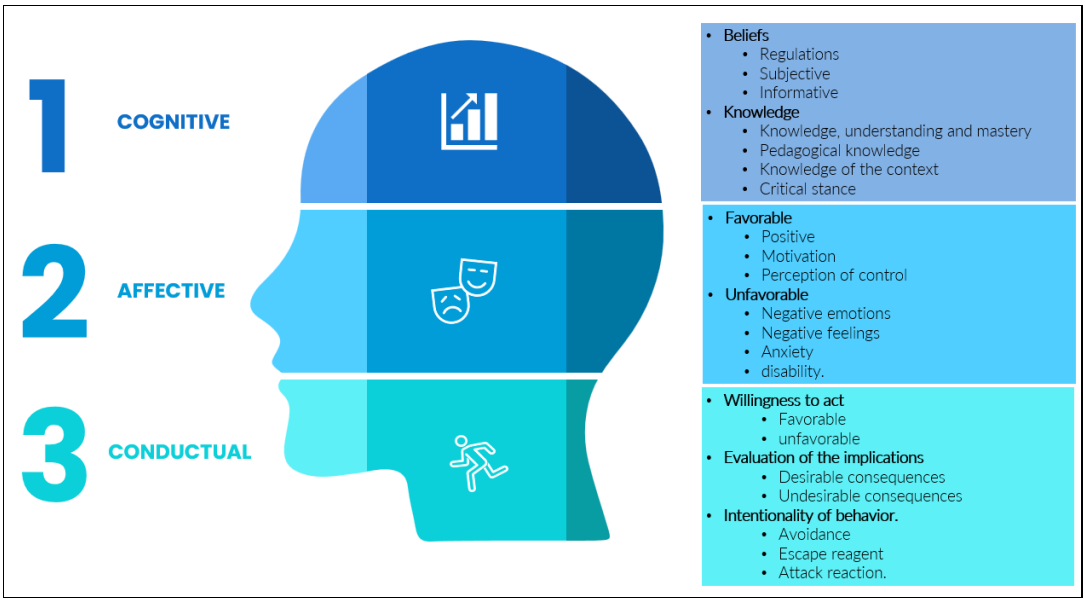

Fig. 2: Model for studying higher education teachers' attitudes towards statistics

Results and Discussion

The systematic study of attitudes is a 100 years old discipline with theoretical-methodological discrepancies. Social psychologists have contributed significantly to the field and allowed the elucidation of some aspects of the cognitive, affective, and behavioral components, such as the theory of reasoned action and the theory of planned behavior of Ajzen and Fishbein (1980). It is crucial to understand whether the subject calculates the cost and benefit of each action undertaken and the perception of control.

Furthermore, its measurement has been the object of developing well-known and used techniques. In 1928, Thurstone exposed the first three ways of measuring attitudes: The method of paired comparisons, the Method of equal appearing intervals, and the Method of successive intervals. Later, in 1932, Likert proposed his famous sigma method of scoring, which initially had seven answer options. Later in 1957, appeared Osgood's Method of semantic differential. There are also lesser-known ones like Guttman's scalogram and Bogardus's social distance scale.

Although the theory, the method, and the techniques continue to cause controversy, the authors establish a model that explains the attitudes towards statistics in higher education teachers, trying to correct some of the elements that have generated the most confusion.

The model needs to be put into practice. For this purpose, we call on specialists in the area to construct and deconstruct the proposal so that empirical evidence will allow us to establish new horizons. It should be noted that the measurement scale according to the model "attitudes towards statistics of teachers who teach in higher education" has already been formulated and is in the process of content validity by a group of experts in research, statistics, and higher education.

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Author's Contributions

Ericka Matus and Lorena Matus: Devised the main conceptual ideas, proof outline, and technical details, performed numerical calculations, and wrote the original draft.

Lucas Rodriguez and Svetlana de Tristán: Verified the numerical results by an independent implementation and reviewed the original draft.

All authors provided critical feedback, have read and agreed to the published version of the manuscript.

Conflict of Interests

The author declares that there is no conflict of interest. Funders have no role in research design, collecting, analyzing, interpreting data, writing manuscripts, or deciding to publish results. The funders had no role in the study design, collection, analyses, or interpretation of data, in the writing of the manuscript, or in the decision to publish the results.

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