RIDU Revista Digital de Investigación en Docencia Universitaria
e-ISSN: 2223-2516

V. 13, nº 2, jul-dec | PERÚ | 2019
http://doi.org/10.19083/ridu.2019.1081

THEORETICAL ARTICLE

Statistics Training at the University Level: Challenges and Opportunities

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Received: 29/06/2019 *Revised: 15/10/2019* *Published: 15/12/2019*

Abstract

The training on statistics is a phenomenon that has sparked great interest in recent years, which is evidenced by the increase in the number of research work at all educational levels. Technological development has brought with it important changes to society and has produced an immense amount of information that grows daily, which is why a different type of citizen and professional is needed; one who is able to understand and interpret the information that surrounds him or her. However, university students show unfavorable attitudes towards statistics, which can be seen in the unsatisfactory results in terms of learning and application. This is a bibliographic-documentary research that examines the elements that take part in the statistical teaching and learning processes at the university level. The exhibition is organized in four parts: the first presents the problems of statistical education in university classrooms; the second explains the cognitive levels involved; the third presents seven teaching models; and the last one examines the implications for the future of statistical education at the university level.

Keywords: didactics of statistics; higher education; statistical education

La educación estadística en el nivel universitario: retos y oportunidades

Resumen

La educación estadística es un fenómeno que en los últimos años ha generado mayor interés, evidenciado en el incremento del número de investigaciones en todos los niveles educativos. El desarrollo tecnológico ha traído consigo cambios importantes en las sociedades, y ha propiciado una inmensa cantidad de información que crece diariamente, por lo que se necesita a otro tipo de ciudadano y profesional, que sea capaz de entender e interpretar la información que lo rodea. Sin embargo, los estudiantes universitarios muestran actitudes desfavorables hacia la estadística, lo que se ve reflejado en resultados insatisfactorios en término de aprendizaje y aplicación. Se trata de una investigación bibliográfica-documental que revisa los factores implicados en los procesos de enseñanza y aprendizaje de la estadística en el nivel universitario. La exposición se organiza en cuatro partes, en la primera, se presenta la problemática de la educación estadística en las aulas universitarias; en la segunda, se explican los niveles cognitivos involucrados; en la tercera, se exponen siete modelos de enseñanza y en la última se discuten las implicancias del futuro de la educación estadística en el nivel universitario.

Palabras clave: didáctica de la estadística; enseñanza superior; educación estadística.

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A educação estatística no âmbito universitário: desafios e oportunidades

Resumo

A educação estatística é um fenómeno que nos últimos anos tem gerado muito interesse, evidenciado no aumento do número de pesquisas em todos os níveis educativos. O desenvolvimento tecnológico trouxe consigo mudanças importantes nas sociedades, e tem propiciado uma imensa quantidade de informação que cresce diariamente. Portanto, é preciso outro tipo de cidadão e profissional que seja capaz de entender e interpretar a informação que o rodeia. No entanto, os estudantes universitários mostram atitudes desfavoráveis para com a estatística, fato refletido nos resultados insatisfatórios em termos de aprendizagem e aplicação. Trata-se de uma pesquisa bibliográfica-documental que revisa os fatores implicados nos processos de ensino e aprendizagem da estatística no âmbito universitário. A exposição organiza-se em quatro partes; na primeira, apresenta-se a problemática da educação estatística nas salas de aula universitárias; na segunda, explicam-se os níveis cognitivos envolvidos; na terceira, expõem-se sete modelos de ensino e na última discutem-se as implicâncias do futuro da educação estatística no âmbito universitário.

Palavras-chaves: didática da estatística; ensino superior; educação estatística.

Como citar:

Ramos, L. (2019). La educación estadística en el nivel universitario: retos y oportunidades. *Revista Digital de Investigación en Docencia Universitaria, 1*3(2), 67- 81. http://doi.org/10.19083/ridu.2019.1081

At present, the development of information society, the rise of technology, and the need to interpret the abundant information available have made statistics become more important (Ruiz, 2015) in citizen participation and both personal and work decision-making. This wealth of information implies a greater need to develop statistical skills in students at all levels, especially in university students (Blanco, 2018).

Salinas & Mayén (2016) state that learning statistics has become indispensable for citizens, since it allows them to analyze, interpret, and make decisions based on the available information. In this sense, Zapata (2011) states that "the common citizen faces the permanent challenge of reading and interpreting statistical data that come from different sources. Unfortunately, our citizens have insufficient statistical literacy to successfully meet the challenges our culture demands" (p. 234).

This statistical literacy is a fundamental element in modern society, since citizens need statistical training to understand the space in which they develop. This will allow them to critically evaluate data in social contexts and will provide them with the ability to make informed decisions. Being a statistically literate citizen has become necessary for everyone, regardless of our occupation, social class or educational level, making statistics an important part of general education every citizen must understand (Sanoja & Ortíz, 2013).

Statistical education is considered an emerging discipline in continuous consolidation and expansion (Andrade, Fernández, & Alfonso, 2017), which is making great progress, even greater than other branches of mathematics, in terms of its extension as well as its depth (Batanero, 2018). Its production is increasing around the world and at all education levels, as it is being implemented into the school curriculum of various countries at the primary (Ruiz, 2015; Alsina, 2017), secondary, and higher education levels (Toapanta-Toapanta, Pérez-Narváez, & Lema-Yungan, 2018), as well as in most university programs (Comas, Martins, Nascimento, & Estrada, 2017), which is therefore developing a statistical culture (Behar, Grima, Ojeda, & Cruz, 2013).

In view of the above, it is understood that the course of statistics has great importance in the professional and civic development. However, students' perception towards the course is usually negative, even though they recognize its importance within their training.

Behar and Grima (2004) claim that, when talking about the problems in the teaching of statistics, the following aspects should be taken into consideration: the high levels of anxiety that it generates, the negative attitudes towards it, the course content (excessively focused on probability and mathematics) that shows little relation with the real world, the lack of motivation of students, the frustration of some teachers for not seeing the results of their efforts, the influence of technology on learning, and whether teachers are really clear about what they want from students regarding statistics education. Statistics has been considered the most feared course and it may even be the one that generates greatest anxiety in undergraduate and graduate students (Onwuegbuzie, 2004), especially in university programs related to social sciences (Paechter, Macher, Martsvishvili, Wimmer, & Papousek, 2017). Some students even consider it as the most feared subject in the curriculum (Molina, Rodrigo, & Bonavia, 2011). This situation has led to the formulation of statistics-related terms when studying these phenomena, for example: statistical anxiety, often found in scientific literature (Mason & Reid, 2018), and the term 'Statisticophobia' (Dillon, 1992) which means being afraid of statistics.

A strong relationship between students' attitudes towards statistics and their outcomes in the course has been documented (Smith, 2017). Comas et al. (2017) explain that "attitudes are an integral part of all learning subjects and occupy a central place in the educational process, guiding the perceptual and cognitive process found when learning any educational content" (p.480). For a large number of university students, the course of statistics implies a cognitive and affective contradiction regarding the teaching and learning processes, since the student understands that statistics is a very important science used to analyze data in scientific research studies; however, the subject is tedious, boring, or even perceived as a source of anxiety (if they could, they would possibly avoid it). From the point of view of attitude towards statistics, this conflict between the cognitive and affective dimensions influences a third dimension called behavioral dimension: at the intellectual level, students recognize the importance of statistics, while they are not inclined to use it at the affectionate and behavioral level. Pérez, Aparicio, Bazán, and Abdounur (2015) conducted research on attitudes towards statistics in Colombian university students and found that, although students recognize the importance of statistics, they show distrust of its use, the skills needed, and the taste for the discipline.

Many students face this course with unfavorable attitudes. The course professors need to be prepared to work on these attitudes and change them. Nevertheless, the challenge is even greater, since many teachers do not have these skills, either because they do not know about teaching methods that facilitate the learning of statistics or because they do not have favorable attitudes towards the subject, which means that these negative attitudes can be transmitted within what is known as the hidden curriculum. Tarazona, Bazán, and Aparicio (2013) state that teachers can unconsciously transmit both positive and negative attitudes to their students, which can affect their learning. If we consider how little preparation some professors have for teaching this course, the situation becomes more complicated. In this regard, Estrella (2017) explains that the poor preparation in the teaching and learning of statistics that teachers in training and in service have is a problem observed when trying to promote and improve the capacity of students to think statistically.

Considering this problem of teaching statistics, this review article analyzes the factors involved in the teaching processes that impact the learning of statistics in the university context. This is a documentary literature research. The topics addressed are presented in the following order: analysis of statistical education at university, cognitive levels suggested for the teaching-learning processes of the subject, description of seven didactic models for teaching statistics, and a discussion on the implications for the future of statistical education.

Statistics Training at the University Level

Many university classrooms still maintain traditional education models that are too focused on content delivery and leave students and their learning achievements in second place. Such models have shown little effectiveness when evaluated (in terms of student learning), which has led to the creation of new models that are more focused on the process and how it can be improved.

Statistics is one of the courses that have the greatest presence in the curriculum of all university programs. However, as mentioned above, a peculiar phenomenon can be observed: despite recognizing that statistics is important for the development of science and society, professors who teach statistics, mainly in programs such as psychology, sociology, education, and communication sciences, see that their students have an unfavorable attitude towards the learning of the course (Rodriguez, 2011), and they even show this attitude before having taken any statistics course (Tarazona et al., 2013).

In art courses, students who begin studying statistics do not have a strong mathematical background and often avoid activities that involve numbers, and even the threat of working with numbers can be enough for a student to drop out or change courses (Dempster & McCorry, 2009). Considering this negative inclination towards statistics, it is recommended that teachers conduct an initial evaluation of attitudes towards the subject. This is very important, since having a certain attitude involves evaluating the object of study, and this evaluation inherently influences the person as a predisposition to respond in a certain way. If the course professor intends to change his or her students' attitudes, it is more likely that students will ultimately learn the subject and use statistics outside the classroom.

It is possible that this negative predisposition towards the course is due to past experiences that generated unpleasant emotions associated with subjects that include numbers, such as mathematics and physics. Ruiz de Miguel (2015) conducted a non-experimental study with an ex post facto design on attitudes towards statistics and found that students approach it with distrust and that their attitudes vary according to their previous experiences. Dempster and McCorry (2009) studied the relationship between previous experiences in mathematics, statistics, and computer science in 103 undergraduate psychology students whose average age was 19.34(2.64) years, and of whom 78% were women, who answered the Attitudes Towards Statistics Scale (SATS-36) and conducted a course evaluation. With this information, the authors found that the best indicator for the attitudes was the students' perceptions of their mathematical skills, at least at the beginning of the course, while the best predictors at the end of the course were the knowledge and skills developed. Praetcher et al. (2017) explain that having success when learning statistics is subject to prior success in mathematics during school times. However, García Martínez, Fallas-Vargas, and Romero-Hernández (2015) found that students who claim to have studied statistics within the contents of another subject have worse attitudes than those who have not received such training, which indicates the importance of linking contents and subjects in statistical training. Although this study will not deal extensively with the emergence of negative assessment towards the subject, the reader is recommended to review the articles of Behar, Grima, Ojeda, and Cruz (2013); Bertorello, Albrecth, and Tauber (2010); and Blanco (2008) for a better understanding of the topic.

In summary, students know that statistical training is important, but they (and sometimes even professors themselves) show negative emotional reactions, attitudes, and beliefs towards the course, generating little interest for its learning (Blanco, 2008). Taking this statement as a starting point, one may ask what actions should be taken to develop the required skills, which—after taking the course—should not be left in a printed syllabus without being adjusted to reality.

Currently, statistical education at the university level is evolving dramatically, from models that focused only on knowledge delivery to models that question which subjects to include and how to teach the student. The efforts to understand this phenomenon have been and are diverse; some aim to improve the experience of students and teachers through showing its usefulness as a pillar of the scientific method, while others highlight the importance of using metaphors to facilitate its learning (Thomas, 2007). Other methods include planning theoretical and practical classes with the implementation of reading and interpretation of scientific articles with statistical content (Diaz-Reissner & Quintana-Molinas, 2018); using mnemonics for the retention and recovery of statistical information (Lesser, 2011); evaluating the different attitudes towards statistics (Bertollero et al., 2010; Blanco, 2008; Estrada, 2002); promoting active and collaborative methodologies among students, by incorporating new technologies and the use of real examples and empirical data to illustrate their methodological concepts (Molina et al, 2011); changing the course structure to reduce anxiety levels (Mason & Reid, 2018); following the JAPEST strategy, which encourages working in groups and solving real problems (Acosta & Mejía, 2017); teaching statistical problems with the use of Information and Communication Technologies (Vázquez, Aguilar, Chávez, Bony, & Montes de Oca, 2016); and, in recent years, using gamification to change the attitudes towards statistics, which has obtained positive results (Smith, 2017). Estrella (2017) claims that "in this challenging and dynamic scenario, the Didactics of Statistics (Statistics Education) has become a growing and exciting field of research and development" (p. 174).

The desire to improve the teaching of statistics has generated a large collection of information on how to improve the teaching-learning process of the course. This article is aimed at students and professors of this field of knowledge and seeks to encourage them to use statistics as a pillar of knowledge and a key element in the scientific method. Before developing the didactic models of statistics, it is important to clearly define the hierarchical structure theorized for its teaching.

Cognitive Levels in Statistics Learning

For two decades, research on statistical education has been focused on three terms: literacy (also called statistical culture), statistical thinking, and statistical reasoning (Sánchez & Berenguer, 2014). Campos (2016) considers these three concepts as fundamental competencies for statistical education and adds an additional competency that he calls "critical competency" for the development of Critical Statistics Education. These competencies are important when formulating learning objectives, as these terms guide the course through the design of instructional activities and assessment with the use of relevant instruments. However, these concepts often overlap, making their correct use difficult (Ben-Zvi & Garfield, 2004).

Schield (2017) made a conceptual review of the term "statistical literacy" and found that it has several definitions, which he interprets as a lack of consensus in its definition. Among the definitions reviewed in their article, we can find the one elaborated by the American Statistical Association (ASA) in its GAISE Report (Guidelines for Assessment and Instruction in Statistics, 2005), which defines statistical literacy as the understanding of its basic language (concepts and symbols) and the fundamental ideas of statistics.

One of the most important articles on the definition of these three terms is discussed in the work of Ben-Zvi and Garfield (2004), who state that people often confuse these three terms, so the authors propose specific definitions to identify and differentiate each of them. These are:

- Statistical Literacy: Includes basic skills (organizing data, creating tables, and working with different representations of data) used to understand statistical information or research results.
- Statistical Reasoning: Defined as the way a person reasons with statistical ideas and makes sense of statistical information.
- Statistical Thinking: Involves understanding why and how statistical research studies are conducted and the ideas behind these, such as the concept of variability, the use of appropriate methods according to the data, visual presentation, sampling, and statistical models. Statistical thinking also refers to understanding and using the context of a problem to formulate research and being able to criticize and evaluate the results of other research studies.

As can be noted, statistical literacy is at a lower level, which is expected to be achieved during the school stage, while statistical thinking is expected to be consolidated at the higher education stage. Régnier & Kuznetsova (2014) explain that the major objective of statistical education is the training of statistical thinking. For reflection, it should be noted and questioned whether university students have really managed to reach the first level (statistical literacy) or, in any case, whether it would be necessary to take the appropriate measures (from statistical literacy to statistical thinking) to achieve the higher cognitive level.

Models for Teaching Statistics

Teaching statistics involves studying a phenomenon with many aspects, including epistemological and psychological aspects; the objectives set in the short, medium, and long term; the selection of statistical content and teaching methods; alternatives to ensure students' motivation; various methodologies to improve results, the role of technology, professional statistical problems, and the most common errors when applying statistical methodology (Sánchez & Berenguer, 2014).

Estrella (2017) indicates that the Didactics of Statistics has become a wide field of research and development. In addition, he states that this emerging field provides results on how it can be used in school classrooms, as well as in higher levels such as university, to promote functional, deep, and long-lasting learning. He also claims that there is a great deal of research studies on the didactics of statistics, which has promoted a change in the paradigm of the conceptualization of its teaching. Blanco (2018) explains that the important evolution of this new discipline in the last 10 years poses specific challenges in the field of university teaching.

Witusba (2014) points out that statistics teaching models are used for pedagogical reasons in order to bring students closer to statistical knowledge in a much more practical way, making what is learned replicable. For Orozco, Sosa, and Martínez (2018), the term teaching model refers to "structured plans that can be used to shape a curriculum, design materials, and guide classroom instruction" (p. 447). Therefore, a teaching model comprises a strategy set by the teacher to increase the effectiveness of the teaching-learning process, by modifying the content and material used in the classroom, in order to achieve the replication of what has been learned in contexts both inside and outside the classroom.

Seven models for teaching statistics are presented below. When reading the models presented, bear in mind that they are not mutually exclusive and can be used either simultaneously or individually, depending on the requirements of the course and the context in which the course is taught.

Teaching statistics: making it memorable. Although Sowey (1995) does not actually propose a didactic model, but a set of suggestions to improve the teaching-learning process, it is important to include it because it comprises important concepts that will be addressed in the following paragraphs. Sowey (1995) wrote a very interesting article about the teaching of statistics called *Teaching Statistics: Making it Memorable*. Although it has been more than 20 years since its publication, it is relevant to discuss it because times were different back then, in terms of the use of technology. Sowey, in his role as a statistics professor for over 20 years at the university level, questions the nature of learning and asks himself the question "What makes teaching memorable?" Based on his teaching experience, he answers that two aspects are the most important ones: the sense of structure and the sense of value the course has. The first dimension, called "sense of structure," comprises two sub-dimensions: coherence, which refers to the organized explanation of the topics and the integration of statistics with the discipline, and perspective, which involves the progressive construction of knowledge. The second dimension, called "sense of value," comprises two sub-dimensions: intellectual interest, which refers to the transmission of the teacher's interest to students through the use of demonstrations to awaken curiosity and promote reflection, and resilience, which encompasses the student's ability to face challenges (which promotes long-term learning). To delve into the topic, we recommend reading Sowey (1995).

PPDAC Model. Wild & Pfannkuch (1999) propose a didactic model based on the solution of research problems (from formulation to conclusion), which comprises four dimensions: the research cycle (dimension 1), types of thinking (dimension 2), the cycle of questions (dimension 3), and conclusions (dimension 4). This model was the product of a series of interviews with psychology students and professional statisticians who helped to formulate a framework to describe the processes involved in statistical reasoning. Estrella (2017) explains that the PPDAC cycle (whose initials stand for: Problem, Plan, Data, Analysis, and Conclusion) provides a framework for modelling statistical problems because it addresses real problem situations (adaptable to any science) through the application of statistics. Figure 1 shows a summary of the PPDAC research cycle proposed by Wild and Pfannkuch (1999), and it has added contributions from Estrella (2017).

Guidelines for Assessment and Instruction in Statistics Education (GAISE).

Blanco (2018) states that, since the beginning of the 21st century, the American Statistical Association (ASA) has promoted and financed a set of guidelines for teaching statistics called Guidelines for Assessment and Introduction in Statistics (GAISE). The final result was a report published in 2005, which addressed the introductory teaching of statistics at the university level. In 2016, these guidelines have been updated and "constitute a good summary of ASA's vision regarding what should be included in an introduction to statistics today" (p. 255).

Schield (2017) reviewed this report and found that the 2005 version had statistical literacy as its main objective, but that the 2016 review replaced statistical literacy with statistical thinking as its main objective. This change is evident in the first recommendation of the 2005 version that stated, "to emphasize statistical literacy and develop scientific thinking," which was replaced by "to emphasize scientific thinking" in the 2016 revised version. Nevertheless, the same paper concludes that achieving statistical literacy is required to move towards statistical reasoning and thinking. Estrella (2017) indicated that the GAISE report provided a framework that includes four main components: asking questions, collecting data, analyzing data, and interpreting results. These stages are similar to those seen in the PPDAC Model, except for the second point of this model, which includes a specific stage for planning.

This report is divided into two parts: the first one emphasizes statistical training in basic level educational institutions, whereas the second one focuses on statistical training in universities. Both reports can be downloaded free of charge from the ASA website. As this article deals with the problem of university students, it only includes information relevant to the topic.

ASA (2016) makes the following recommendations for introductory instruction at the university level: a) teach statistical thinking; b) focus on conceptual understanding; c) integrate real data with context and purpose; d) encourage active learning; e) use technology to explore concepts and analyze data; and f) use examinations to improve and evaluate student learning.

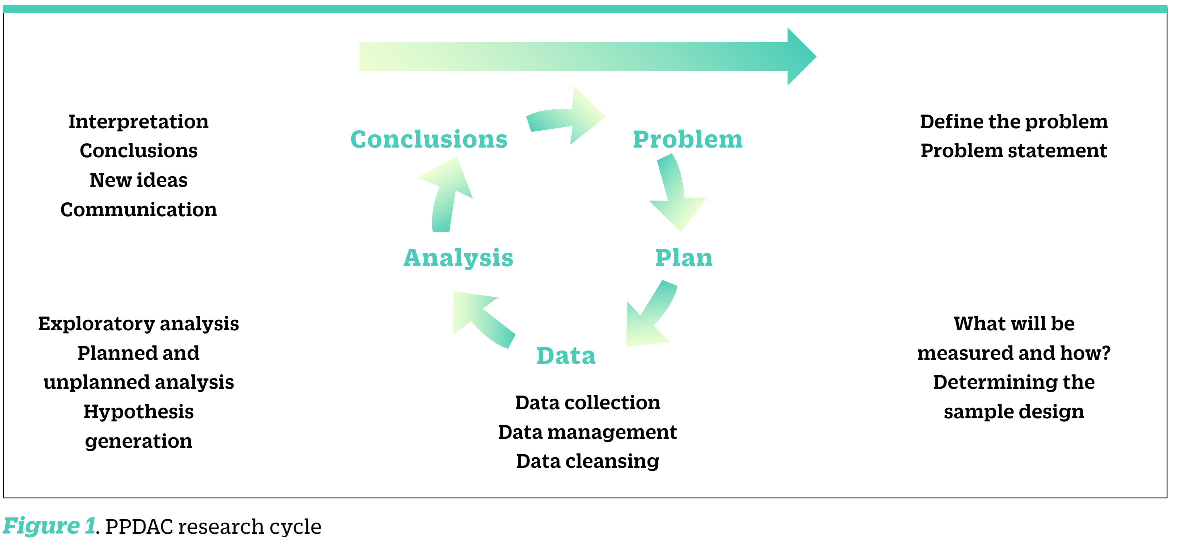

Figure 1. PPDAC research cycle

ASA (2016) explains that, in order to achieve these recommendations, it is required that students masters statistical techniques that facilitate the understanding of statistical concepts and the principles behind these techniques, thus the association does not recommend introducing specific topics to be taught in the course. Blanco (2018) states that "the report also points out some topics that could be omitted in an introductory course: probability theory, manual construction of graphs and Basic Descriptive Statistics, use of statistical tables, and advanced training in statistical analysis programs" (p. 258).

Informal statistical inference (ISI).
Rodríguez (2012) explains that, at the university level, all introductory statistics courses aim to develop statistical inference methods. This is one of the most widely taught subjects, but at the same time, it is the least understood and used. Since statistics courses require gradual progress, from the simplest to the most complex topics, students are required to clearly understand what statistical inference is and what it is for.

The term "informal" means that it is part of the ordinary knowledge of the student, that is, the knowledge that students have before entering the classroom, outside of class, in everyday life. It is necessary to consider the importance of previous knowledge, as it is the starting point for achieving learning (Rodríguez, 2012).

García (2013) explains that Informal Statistical Inference is a type of reasoning between exploratory data analysis and formal statistical inference and points out that the term "informal" refers to the possibility of using it outside of formal procedures. Estrella (2017) claims that the ISI consists of making inferences about the population based on random samples of data collected by students. By analyzing these data, the generalization will be made by means of a probabilistic language, emphasizing certain uncertainty about this inference.

The reasoning promoted by the ISI is of great importance, because students use their informal knowledge to support the inferences made from the samples (Rodriguez, 2012). García (2013) explains that the analysis of students' informal inferential reasoning is carried out considering four components: a) conclusions beyond data (which involves making judgments, statements, or predictions about populations based on the data collected from the sample, without using the formal techniques and procedures; it also includes making estimates of uncertain phenomena), b) the use of data as evidence (which involves articulating arguments to make judgments, statements, or predictions about the population; basing conclusions on the patterns of the available data, and focusing on the generalization of results to achieve students' understanding), c) the use of probabilistic language that expresses uncertainty of the conclusion (in formal statistics, students make statements that are not absolutely certain, and understand that a prediction is only an estimate), and d) the use and integration of previous formal and informal knowledge (inferences are drawn from the available data, and must be accompanied by a theory (scientific or personal) that allows such a generalization to be made and interpreted.

The studies of García (2013) and Rodríguez (2012) present cases on the use of informal statistical inference in class.

Cultural models in the teaching of statistics.
Witusba (2014) states that a didactic model does not come out of nowhere, yet it is the product of teaching practices, their didactic organization, and collaborative efforts. The cultural models refer to didactic models, mainly used at the school level, but it should be noted that it is possible to apply them at higher levels. However, as the reader must have deduced, the cultural models are primarily used for statistical literacy. The author also explains that cultural models focus on what culture has validated, which means that "what is learned is replicated." In other words, they have a pragmatic-oriented component. In these models, the division is considered between interpretative models (IM), characterized by understanding the delivery of the information already processed to be read and interpreted by the student; operational models (OM), characterized by establishing the exploratory and operational analysis of the data through the use of central tendency statistics to describe the information; and the productive research model (PRM), characterized by generating information of original nature, using the research methodology. Table 1 shows a summary of the three models explained by Witusba (2014).

Table 1

Cultural Models in Statistical Education

	Interpretative Models	Operational Models	Productive Research Models
Learning vision	The visualization of information facilitates reflection.	The practice of statistical analysis promotes learning.	To integrate statistics as part of the research process.
Objective	To interpret and compare information through graphs and use them to hypothesize relationships.	To understand statistical procedures through the elaboration of frequency tables and the calculation of statistics.	To develop and implement research projects that encourage students' interest in answering questions through the use of statistics.
Material used and actions required	Payment slips Consumer products information Situations of experiential nature (weight, height, etc.)	Raw data delivery. Raw data collection.	Elaboration of a research project. Work planning. Data collection.

Statistical Reasoning Learning Environment (SRLE).

Estrella (2017) states that the Statistical Reasoning Learning Environment (SRLE) consists of an environment that promotes statistical reasoning so that students achieve a deep understanding of statistics. Ben-Zvi (2011) explains that this model is based on the theory of socio-constructivist learning and teaching, and that it has six pedagogical principles: it focuses on the development of core statistical ideas, rather than techniques and procedures; uses real, motivating data to increase students' interest in making and testing guesses; uses classroom activities to support the development of students' reasoning; integrates the use of appropriate technological tools that allow students to test their conjectures, explore and analyze data, and develop their statistical reasoning; promotes a classroom discourse that argues through the use of statistical terms that address statistically significant ideas; and uses diagnosis to learn what students know and to monitor the development of their statistical learning to evaluate instructional plans and progress.

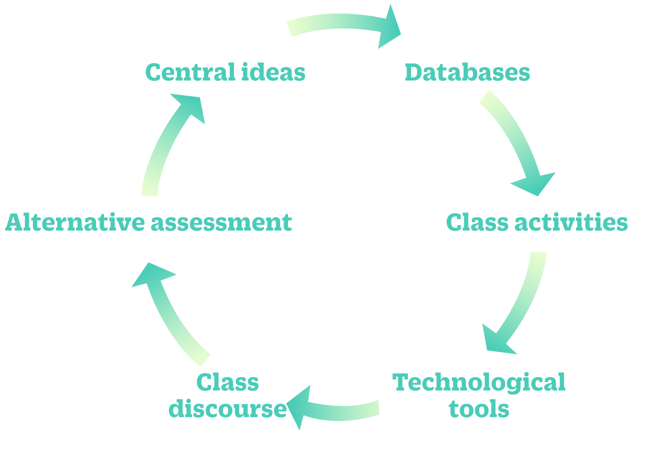

Figure 2. The six elements of the SRLE

This model is called learning environment because it is an interactive combination of text materials, classroom activities, standards and culture, discussion, technology, teaching approach, and assessment. Figure 2 presents the six elements that comprise the SRLE shown in Ben-Zvi's (2011) study.

In Ben-Zvi's study (2011), there are two examples of the model's application in real situations: the first one for university environments, and the second one for school environments.

Gamification of Learning in Statistical Education

Gamification is based on the use of videogame elements used in different contexts on the same game. There have been attempts to gamify activities in diverse sectors, such as education, companies, human resources, etc. (Ortíz-Colón, Jordán, & Agredal, 2018).

Landers (2015) proposes a theory of game-based learning based on five main statements: instructional content influences the learning outcomes and behaviors/attitudes; the behaviors/attitudes influence learning; game characteristics influence behavior/attitude change; game elements affect behaviors/attitudes that moderate instruction effectiveness, and the relationship between game elements and learning outcomes is determined by behaviors/attitudes. Figure 3 shows a diagram developed by Landers (2015), which summarizes his theory.

There is not much information available about gamification in statistical courses, yet the results are promising. Boyle et al. (2014) conducted a literature review on the subject. For searching information, they used search criteria related to games, simulations and animations, gamification, e-learning, and computer-assisted learning, and found 26 studies from the ERIC, EBSCO (PsycINFO, SocINDEX, Library, Information Science and Technology Abstract, CINAHL), and ASSIA databases about how the use of digital games, simulations, and animations allowed students to achieve the learning objectives in methodology and statistics courses, concluding that there are reasons to be optimistic. Game-based approaches can be effective for learning in this area. In a recent study, Smith (2017) used Landers' (2015) theory to conduct research on how instruction through game-based modules in a statistics course affects learning and attitudes toward statistics in undergraduate students, and found that students who received game-based instruction had positive changes in their attitudes and learning of statistics. This result provides initial evidence for the effectiveness of a game-based approach in statistics courses.

The reader is encouraged to review the studies of Landers (2015); Landers, Auer, Collmus, and Armstrong (2018); Smith (2017), and Ortiz-Colón et al. (2018) to learn more about game-based learning. The research conducted by Barreal, Hernández, & Jannes (2016) includes a detailed proposal of a game-based program.

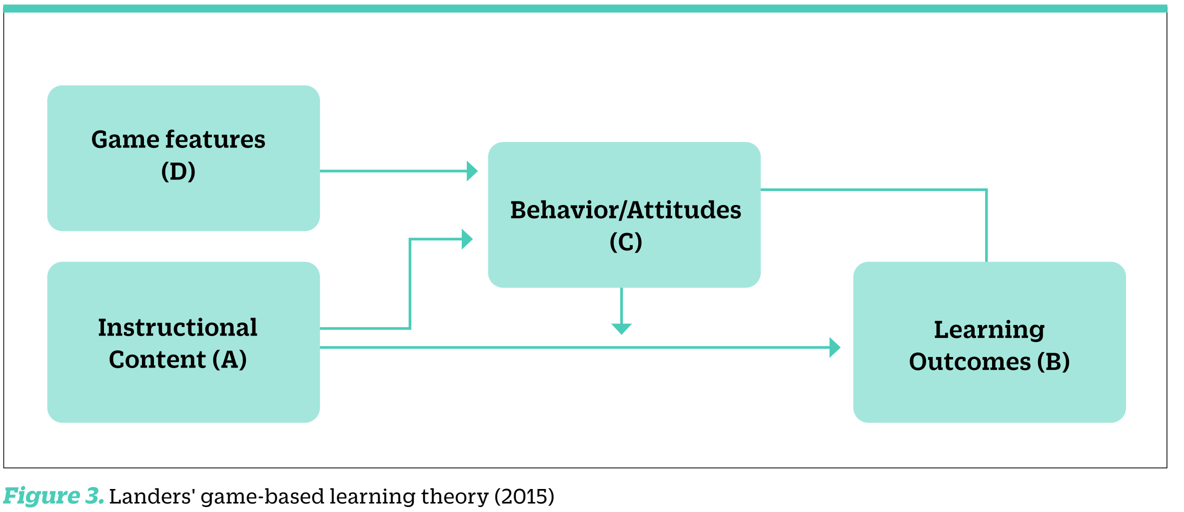

Figure 3. Landers' game-based learning theory (2015)

Discussion

We are living in a unique moment in the history of humanity, characterized by a technological revolution comparable only to the industrial revolution in terms of the impact on human life. This technological revolution has established new ways of interacting and has exponentially increased the amount of information available to us, which is now infinite and continues to grow at an accelerated pace every day.

This accelerated growth of information has become a fundamental part of the development of societies. Acosta and Mejía (2017) explain that “the relationship between a country's development and the level to which its statistical system produces complete and reliable statistics is clear, because this information is necessary for making right economic, social, and political decisions” (p.3). Therefore, it is necessary to provide new citizens with relevant skills to understand and analyze data, so they benefit from the opportunities that working with this type of information entails, especially in the context of training schoolchildren and professionals, who must have the tools and skills needed to be able to take advantage of the large amount of economic, educational, social, cultural, and political information around them (Rodríguez-Alveal, 2017). This will make statistical education become a motor for social and individual development (Batanero, 2018).

Statistical education at higher levels is presented as both a challenge and an opportunity. It is a challenge due to the existence of a particular problem in its teaching-learning processes, which is more evident in this course than in others. This problem is mostly present in a large number of university classrooms and is especially noticeable in programs that are not very related to mathematics (Rodríguez, 2011). Among the characteristics of this problem, we can mention the high levels of anxiety, unfavorable attitudes, students’ lack of motivation and interest, professors’ frustration for not being able to improve processes, and fear of the subject (Behar & Grima, 2004; Molina et al., 2011). It is especially interesting to consider the role played by attitudes, since they refer to the way in which a person responds to something or someone. In this case, it reflects how the subject responds to statistics, which makes the individual act according to the beliefs, thoughts, and emotions related to the object of the attitude.

While students may understand at a cognitive level that statistics is important for scientific research and the development of science, at an affective level they may have hostile reactions to the course, which generates a conflict in what they think and how they feel. Because of this conflict, students are inclined not to focus on the course nor to make an effort or be interested (at a behavioral level) in its learning and application. In any statistics course, regardless of the major, one of the goals that professors should set involves changing attitudes towards statistics, since positive attitudes are expected to improve the students’ learning process and increase their performance on course evaluations, making them implement their statistical skills in professional life (Kiekkas et al., 2015).

The subject of statistics is presented as a challenge because of the inherent difficulties that a course of this nature involves. It is also an opportunity for teachers to strengthen their skills and to come up with creative strategies that achieve significant changes and promote the development of statistical thinking, which implies that professors must be professionals who are constantly preparing themselves to teach statistics. If they use traditional teaching models, which are too focused on the content and application of mathematical procedures without emphasizing the usefulness and interpretation of results, their teaching methods will probably have a counterproductive effect on students, who, instead of being attracted to this science, will have more negative reactions compared to how they began attending their statistics classes on the first day. Blanco (2018) explains that today's statistics is very different compared to last century, since, due to the large amount of data, its methods have been changing and expanding, which has required new ways of processing information, modifying how people think and how they learn from data. These changes have promoted a great interest in the study of the didactics of statistics.

Currently, statistics courses, in any university program, should be planned with the aim of developing students' statistical thinking. This is an ideal scenario, yet many students are at lower levels or, even worse, some of them have not yet reached basic levels such as statistical literacy or reasoning. At the university level, some shortfalls of statistical education at basic education levels have to be overcome to reach the higher cognitive level, which is statistical thinking. The use of these cognitive levels for teaching has been a major factor in establishing relevant milestones in the process, which Behar and Grima (2004) express as follows:

> It sounds reasonable to start by discussing and reflecting on what we intend to achieve with our statistics course, because having a clear idea of our point of arrival and knowing our starting point, we will have greater chances of success in drawing up a route that tries to connect those points (p.86).

The opportunity teachers have by teaching the statistics course requires them to play an active role as a researcher on their didactics, so that they can learn about current teaching models, evaluate them, and choose one or two that fit the needs of the course. Among the didactic models presented, the reader is encouraged to initially review the one proposed by ASA (2016), which is considered to be one of the most important one in the teaching of statistics. The achievement of the goals suggested in this report will make an impact in the short term, and, coupled with the relevant application of the other models, will succeed in developing statistical thinking in students.

Within the recommendations, limitations, and projections resulting from this review, we can list three large sections that address some problems in the study and application of didactics of statistics in the university context. The first one comprises the study of attitudes towards statistics, which is playing a very important role in the teaching and learning processes of the subject. Attitude assessment is also growing significantly regarding methodological aspects, the creation and validation of instruments, aspects of applied research, and the evaluation of the impact of programs to change different attitudes towards statistics courses. The second section refers to the evaluation of students' skills. It is important to conduct studies on the ability of university students to solve statistical operations, either manually or assisted by technology, and to determine the cognitive level (statistical literacy, reasoning, or thinking) students have when taking the course. Although students might be motivated to learn statistics (favorable attitude), they may not have adequate prior training, which could affect the achievement of the subject competency. The third one is related to which teaching model professors choose. From the beginning, they must identify both the starting point and the ultimate goal (the point of arrival), which involves evaluating the students' attitudes and skills and the context of the class. Therefore, they must consider the number of students in the classroom, the access to technology, the students' interests, the relationship between the content and the professional program, their own knowledge and attitudes towards statistics, among other factors that may influence the process. Having this information, professors must propose actions based on the evidence, which can be evaluated and promoted to enrich this line of research.

As a final reflection, readers have been able to appreciate general aspects about the didactics of statistics, such as the teaching problems, the cognitive levels in its learning, and the presentation of didactic models to be applied in class, so now they have an idea of how much work is required in this exciting field. The educational researcher must understand that statistics is not only a tool for data processing, as it is also an intelligent way of seeing the world, one that encourages evidence-based decision making and problem-solving in everyday life, which benefits both the individual and society in general.

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