ATTITUDES RELATED TO STUDENTS' PERFORMANCE IN STATISTICS IN UNIVERSITY PROGRAMS IN ARGENTINA

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ABSTRACT

Students from non-statistics degree programs often perceive statistics as a burden, underestimating its usefulness and encountering difficulties that cause them anxiety and stress, which may lead many of them to fail statistics courses. Students' attitudes can hinder their learning and development of useful skills associated with statistical thinking, which should be later applied outside the classroom. The aim of this study was to analyze students' attitudes towards statistics in introductory courses in three schools of Argentina, enrolled in Agricultural Sciences and Biological Sciences. We analyzed students' attitudes at the beginning and at the end of the courses, the differences between pre- and post-course attitudes, and the relationship between these changes and students' performances. The sample consisted of 436 students and their attitudes were measured using the Survey of Attitudes Towards Statistics (SATS-28), considering four components: Affect; Cognitive Competence, Value, and Difficulty. Students' performances were classified as: passed (and exempt from final exam), intermediate (but not exempt from final exam), and failed. Difficulty was not related to students' performance, as opposed to what was detected with the other components. Cognitive competence was the only component that classified students' performance in the correct order. Students who failed the course differed from the rest in that they developed more negative feelings towards statistics at the end of their course; in contrast, students with good performance showed an increase in the value given to statistics. Biological Sciences students presented higher average scores in the four components studied.

Keywords: *Statistics education research; SATS; Attitude; Student performance; Affect; Cognitive competence, Value, and Difficulty*

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1. INTRODUCTION

Being able to offer good evidence-based arguments and critically assess the data available are skills that every person should have. In this sense, the ability to think statistically in a context of uncertainty and to make decisions in this context is relevant. Although statistics has been included in many non-statistics degree programs, students often perceive it as a burden, underestimating its usefulness and encountering difficulties that cause them anxiety and stress, which potentially lead many of them to fail the course. Students' attitudes and beliefs may either hinder or support the learning of statistics processes and affect the development of useful statistical reasoning capabilities outside the classroom (Gal et al., 1997). We agree with Schau (2003) that for students to succeed and use statistics, they should think that it is valuable in their lives, they should like it, they should understand it and use it, and they should think that it is not too difficult. Thus, it is important for students to have positive attitudes towards statistics. If we want to achieve high-quality statistics learning, it is necessary to identify the negative attitudes of students to influence a change. Knowing students' attitudes towards statistics and the way they learn are necessary prerequisites for the development of strategies to improve learning (Byrne et al., 1999). Emmioğlu and Capa-Aydu (2012) defined attitudes towards statistics as a multidimensional construct representing students' learning predispositions to respond positively or negatively.

Several studies have reported that attitudes towards statistics are positively related to students' performance in statistics courses, which indicates that more positive attitudes are linked to higher performance (e.g., Tremblay et al., 2000; Limpscomb et al., 2002; Finney & Schraw, 2003; Nasser, 2004; Chiesi & Primi, 2009; Dempster & McCorry, 2009; Hannigan et al., 2014; Sesé et al., 2015; Milic et al., 2016). Specifically, attitudes at the end of the course have been shown to be better predictors of achievement than attitudes at the beginning of the course (Wisenbaker et al., 2000).

Among the several tools to measure students' attitudes towards statistics, the Survey of Attitudes Towards Statistics (SATS-28) (Schau et al., 1995) has several advantages. First, it is easily adaptable to statistics introductory courses worldwide, as reported by Wisenbaker et al. (2000), Nasser (2004) (Arabic version), Carmona Márquez et al. (2005) (Spanish version), Tempelaar et al. (2007) (Dutch version), and Chiesi and Primi (2010) (Italian version). Second, it provides a multidimensional measure of attitudes. Third, its psychometric properties have been well documented (Schau et al., 1995; Dauphinee et al., 1997; Hilton et al., 2004; Cashin & Elmore, 2005; Chiesi & Primi, 2009). In addition, it is a short and easy-to-administer survey developed for students enrolled in introductory statistics courses and provides versions to be used at the beginning (pre-SATS) and at the end (post-SATS) of the course. Exhaustive studies performed to provide evidence of the validity and reliability of the instruments used for the determination of attitudes (Carmona Márquez, 2004; Nolan, 2012; Ramírez et al., 2012) have concluded that, by means of the structure proposed, SATS is a plausible candidate to describe the dominance of attitudes towards statistics.

In Argentina, from his/her initial learning of mathematics to the first time he/she is confronted with statistics at university (a period that lasts at least 12 years), the student works and reasons in the deterministic field. In our long professional experience, we have noticed that many students start statistics courses with zero knowledge of the subject. The development of statistical reasoning is different from that of mathematical reasoning, and both are essential in modern life (Gattuso, 2006; Scheaffer, 2006). We believe that early training in statistics allows correct reasoning against stochastic phenomena.

In most developed countries, statistics has been incorporated into the mathematics curricula in elementary and higher education and even at Kindergarten level (National Council of Teachers of Mathematics, 2000). The reasons for including the teaching of statistics at these levels have been repeatedly highlighted (Hawkins et al., 1991; Wild & Pfannkuch, 1999; Gal, 2002; Franklin et al., 2005). The key point is the training of statistics teachers at elementary and middle education levels. In Argentina, the basic statistical concepts are taught by mathematics teachers of middle level. Thus, these teachers need to receive good training in statistics knowledge at teachers' training schools.

In a previous study (Fabrizio et al., 2007), we carried out research covering all public and private teachers' training schools of the city of Buenos Aires to get an overview of the situation of the training of mathematics teachers in statistics (their general knowledge in statistics and how they apply it to everyday questions). In that study, we found that teachers graduate with a wide variety of difficulties and lack of knowledge of statistics, which is likely to be passed on to their students. The lack of confidence in the field leads them to feel uncomfortable teaching it and therefore try to omit it by alluding to lack of time. Teaching statistics solidly and efficiently at the middle education level and even at elementary level will have a qualitative effect on the constitution of future society as it opens the young person's mind to the rational management of uncertainty and randomness. The variability and production of data in statistics differentiates statistical thinking from mathematical thinking. Statistical thinking also depends, to a large extent, on the interpretation and critical judgment of the person (Hannigan et al., 2014).

The aim of the present study was to focus on the relationships between non-cognitive factors, such as the attitudes towards statistics at the beginning and at the end of statistics courses, and students' performance. To this end, we examined students' attitudes in statistics introductory courses in non-statistics degree programs at two schools of Agricultural Sciences and one school of Biological Sciences in Argentina. Specifically, we analyzed:

1. students' attitudes towards statistics at the beginning and at the end of their introductory statistics courses;
2. differences between post- and pre-course attitudes towards statistics and the relationship between these changes and students' performance; and
3. differences between schools in attitudes towards statistics.

2. MATERIALS AND METHODS

2.1. PARTICIPANTS

The sample at the beginning of the study comprised of 436 students from statistics introductory courses: 311 from the School of Agricultural Sciences of the University of Buenos Aires (FAUBA), 96 from the School of Exact and Natural Sciences of the University of Buenos Aires (FCEyN), and 29 from the School of Agricultural Sciences of the National University of Lomas de Zamora (FCA-UNLZ). The last school also included Zootechnics. All three schools are public. A total of 246 out of the 436 students completed the study (181, 47 and 18 from each of the three schools, respectively). The students were enrolled in four degree programs, which, for this study, were grouped as "Agricultural Sciences" and "Biological Sciences". Agricultural Sciences included Agronomy, Environmental Sciences and Zootechnics, and Biological Sciences included only Biological Sciences.

In all programs, statistics courses were mandatory and taught in the second year. The first half of the courses covered topics related to descriptive statistics, probability, and random variables, whereas the second half introduced sampling distributions, hypothesis tests and confidence intervals for the mean and mean differences, simple linear regression, and categorical data analysis. The common feature of the statistics courses was that they all had an approach applied to the field of empirical research in which students were enrolled. The courses lasted 16 weeks and consisted of one theoretical class (lecture) and one practical class per week. The lectures were based on the discussion of theoretical issues without mathematical demonstrations, followed by practical examples. Some of the problems presented in the practical classes were solved using statistical software packages. Regarding the general features of students, 52% were women, 37% studied and worked, and their median age was 21 years old (minimum 19, maximum 46).

2.2. MEASUREMENT INSTRUMENTS

In this study, students' attitudes were evaluated using the Survey of Attitudes Towards Statistics (SATS-28) developed by Schau (2003) at two points of time: at the beginning of the course (pre-SATS) and at the end of the course (post-SATS). The versions used a seven-point Likert scale in 28 items to evaluate four components of students' attitudes towards statistics: *Affect*, *Cognitive Competence*, *Value* and *Difficulty*. *Affect* (6 items) evaluated the students' feelings and emotions linked to statistics. *Cognitive Competence* (6 items) evaluated the perception of self-competence, knowledge, and intellectual skills in the use of statistics. *Value* (9 items) evaluated the appreciation of the usefulness, relevance, and value of statistics in personal and professional life. Finally, *Difficulty* (7 items) evaluated the perception of difficulties in understanding a formula and a technical method.

Students' performance was assessed through two midterm tests (one in the middle of the course and one at the end of the course). Based on their score, their performance was classified into: passed (and exempt from final exam), which referred to students who passed the course with a score equal to or higher than 70/100 and thus did not have to sit for a final exam (*P*) ; intermediate (but not exempt from final exam), which referred to students who had scores between 40/100 and 70/100 and thus had to sit for an integrated final exam (*I*); and failed or below standard, which referred to students with scores lower than 40/100, and they failed to pass the subject (*F*).

2.3. DATA SOURCE

Data were collected during the first half of 2016 by means of two SATS surveys: one at the beginning of the course (pre-SATS) and one at the end of the course (post-SATS). In order to obtain a homogeneous comparison scale in which a higher value indicates a more positive attitude, direct scores were assigned to items that expressed a favorable attitude, and complementary scores to the items that expressed a negative attitude. If students did not respond to one or two items, the items were completed with a neutral value (4); if they did not respond to more than two items, the case was removed. For each student, the value of each component was obtained by averaging the scores of the items for that component. The two surveys had identical items, except for some changes in the wording related to the time of the evaluation (for example: "I'll like Statistics" was changed to "I like Statistics"). Each survey was completed in less than 15 minutes at the beginning of a class. The teachers in charge of the courses were trained to homogenize the data-collection criteria. Teachers encouraged students to respond honestly to what they thought, without fear of possible consequences for their grades. The only reason they had to write their ID number was to match the two questionnaires and their evaluations in the subsequent statistical analysis. All students participated voluntarily.

2.4. STATISTICAL ANALYSIS

SATS consistency was determined by calculating Cronbach's alpha coefficient. Differences between post-SATS and pre-SATS were analyzed using: a) paired sample tests (t test or Wilcoxon tests when normality distribution was not satisfied) to evaluate the statistical significance of the change; b) Principal Component Analysis and a biplot to explore the relationship between attitudes and performance; c) Analysis of Variance (ANOVA) and DGC (Di Rienzo, Guzmán & Casanoves) tests (Di Rienzo et al., 2002) to study the students' performance for the post-pre-course difference in the attitude components; and d) ANOVA with factorial structure to compare groups, performance and their interaction. Assumptions for ANOVA were verified using Shapiro Wilks and Levene tests. When the homoscedasticity assumption was not met, a mixed model was used. Data were analyzed using SAS/STAT® software (2018) and InfoStat (Di Rienzo et al., 2018). The level of significance of each statistical test was 0.05.

3. RESULTS

3.1. VALIDATION OF THE SATS INSTRUMENT

The internal consistency of the attitude components was described by Cronbach's alpha coefficient and compared to other reference values (Table 1). Except for the components *Cognitive Competence* and *Difficulty* in the pre-SATS and the component *Cognitive Competence* in the post-SATS, which showed somewhat lower values, the results obtained were within the ranges reported in studies conducted by other authors.

Table 1. Estimations of reliability of Cronbach's internal consistency

Component	pre-SATS		post-SATS	
	This study	Other studies*	This study	Other studies*
Affect	0.75	0.73 – 0.85	0.78	0.81 – 0.89
Cognitive Competence	0.67	0.72 – 0.84	0.67	0.74 – 0.90
Value	0.77	0.75 – 0.88	0.82	0.63 – 0.92
Difficulty	0.52	0.61 – 0.74	0.56	0.51 – 0.85

* Hilton et al., 2004; Mills, 2004; Nasser, 2004; Cashin & Elmore, 2005; Tempelaar et al., 2007; Wiberg, 2009; Chiesi & Primi, 2009; Sesé et al., 2015

3.2. ANALYSIS OF THE ATTITUDES COMPONENTS

Regarding the mean response for each component of the surveys (Table 2), both in the pre-SATS and the post-SATS, the component *Value* presented the highest mean (greater than 5), showing that students thought that statistics is useful, necessary, and relevant in their studies as well as in their professional and daily life. In contrast, the component *Difficulty* had the lowest mean in both surveys, demonstrating that students thought that understanding a formula or technical method was difficult. In the comparison between post-course and pre-course attitudes, the components improved after the course, except for *Cognitive Competence*, which showed no difference (p-value = 0.54).

Table 2. Comparison of the attitudes towards statistics at the beginning and at the end of the course

Component	pre-SATS		post-SATS		post-pre difference (Δ)		
	Mean	SE	Mean	SE	Mean	SE	*p*-value
Affect	4.57	0.07	4.86	0.07	0.29	0.08	0.0006
Cognitive Competence	4.98	0.06	5.03	0.06	0.04	0.07	0.5399
Value	5.44	0.05	5.55	0.06	0.10	0.06	0.0297
Difficulty	3.47	0.04	3.66	0.05	0.19	0.05	0.0004

Considering only students who completed both surveys, no significant differences between gender and employment situation were found in either component. In terms of students' performance, 51% passed the course (and were exempt from the final exam), 37% had to sit for a final exam and 12% failed.

3.3. ANALYSIS OF STUDENTS' ATTITUDES AND PERFORMANCE COMPONENTS

Figure 1 shows that the differences in the components between both surveys (ΔValue, ΔCognitive Competence, ΔDifficulty, ΔAffect) separated the final performances of the students (Condition). The students who improved their attitude towards statistics at the end of the course tended to pass without the need to sit for an exam (exempt from final exam, P), as can be seen in the 95% confidence ellipse. In addition, ΔAffect and ΔCognitive Competence presented the highest level of correlation (r = 0.66), suggesting that students who were able to better understand the statistical concepts and ideas, and thus to incorporate them into their thinking, felt less threatened, disappointed or stressed as they continued the course. From another point of view, it may be thought that the improvement in the component *Affect* allowed students to incorporate statistical ideas and concepts in greater depth into their thinking.

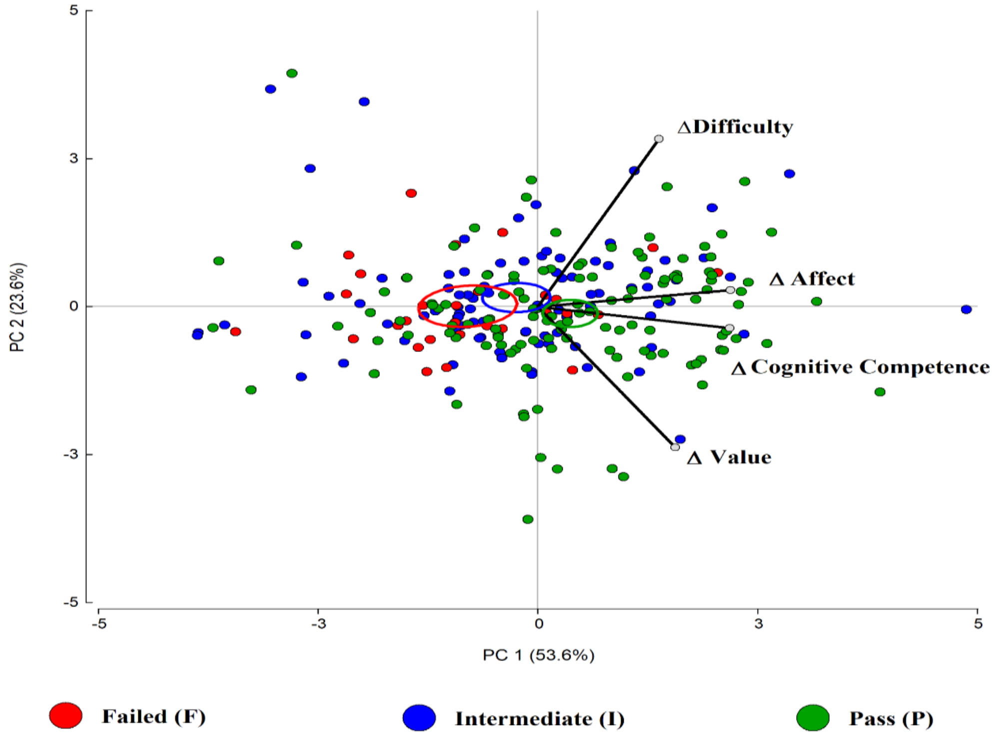

Figure 1. Biplot of the difference between the attitudes towards statistics at the beginning and at the end of the course and students' performance

The univariate ANOVA of the post-pre-course differences (Δ) of the attitude components revealed significant differences between the final results of the students, except for ΔDifficulty. While ΔCognitive Competence separated all three performance categories (passed, intermediate and failed) as expected, ΔAffect separated the students who failed the subject from the rest, and ΔValue separated the category passed (P) from the other two categories (Table 3). It should be noted that, although no significant changes were found in the component *Cognitive Competence* when considered alone (Table 2), this change was not homogeneous for all performance categories. The students' final results explained some of the total variation in this difference. Table 3 shows that the means of the students who passed the course exempt from final exam (P) were positive in all the attitude components. In contrast, those who failed (F) had negative mean differences, except for ΔDifficulty. These results are consistent with those observed in the Biplot (Figure 1).

Table 3. Analysis of the students' performance for the post-pre-course difference in the attitude components

Component	Mean performance			ANOVA	
	F	*I*	*P*	MSE	*p*-value
Δ*Affect*	-0.44 a	0.18 b	0.54 b	1.6249	0.0007
Δ*Cognitive Competence*	-0.55 a	-0.13 b	0.31 c	1.0718	0.0001
Δ*Value*	-0.13 a	-0.10 a	0.32 b	0.9167	0.0018
Δ*Difficulty*	0.04 a	0.19 a	0.24 a	0.7382	0.5557

Δ: difference between the response at the end of the course and that at the beginning of the course
Means with different letters in each row are significantly different (DGC, $p < 0.05$)

3.4. ANALYSIS OF THE ATTITUDE COMPONENTS ACCORDING TO THE SCIENCES STUDIED BY THE STUDENT

Comparisons among the post-pre-course differences of all attitude components, for all students evaluated, revealed that students of Biological Sciences had higher average than those of Agricultural

Sciences (Table 4). It is important to note the magnitude of these differences: in Agricultural Sciences the values approached zero, whereas in Biological Sciences they exceed 0.40 units.

Table 4: Post-pre-course differences in the attitude components between Degree courses

Components	Agricultural Sciences		Biological Sciences		
	Mean	SE	Mean	SE	*p*-value
Δ*Affect*	0.14	0.09	0.91	0.16	0.0002
Δ*Cognitive Competence*	-0.13	0.07	0.75	0.13	<0.0001
Δ*Value*	0.03	0.07	0.42	0.09	0.0014
Δ*Difficulty*	0.12	0.06	0.50	0.11	0.0061

Because none of the Biological Sciences students failed to pass the subject, in the comparison of both sciences (Agricultural Sciences vs Biological Sciences), we only considered students who passed exempt from final exam and those who had to sit for a final exam (217 in total). No interaction between the sciences and students' performance was detected in any of the components studied. This subset of students still showed differences between the two sciences (in favor of Biological Sciences) in all the components (Tables 5 and 6). Differences between the performances of these two groups of students (students who passed exempt from final exam and those who had to sit for a final exam) were detected only in the components ΔCognitive Competence and ΔValue in favor of the students who were exempt from final exam (Table 5).

Table 5: p-values of the ANOVA associated with the factorial arrangement of the sciences and students' performance for the post-pre-course SATS differences in attitude components

Component	Science	Performance	Science*Performance	SME
Δ*Affect*	0.0206	0.0656	0.2946	1.6028
Δ*Cognitive Competence*	0.0001	0.0255	0.5853	1.0139
Δ*Value*	0.0117	0.0007	0.9021	*
Δ*Difficulty*	0.0395	0.6279	0.4359	0.7429

* Heteroscedasticity

Table 6: Means and standard errors of the sciences and students' performance for the post-pre-course SATS differences in attitude components

Component	Science		Performance	
	Agricultural	Biological	*I*	*P*
Δ*Affect*	0.24 [a] (0.10)	0.91 [b] (0.16)	0.18 [a] (0.13)	0.54 [a] (0.12)
Δ*Cognitive Competence*	-0.05 [a] (0.08)	0.75 [b] (0.13)	-0.13 [a] (0.10)	0.31 [b] (0.10)
Δ*Value*	0.03 [a] (0.08)	0.33 [b] (0.08)	-0.02 [a] (0.09)	0.38 [b] (0.08)
Δ*Difficulty*	0.14 [a] (0.07)	0.50 [b] (0.11)	0.19 [a] (0.09)	0.24 [a] (0.08)

Means with different letters in each row are significantly different ($p < 0.05$)

4. CONCLUSIONS

The results of the present study showed higher values in the component *Value* and lower in the component *Difficulty* after the course, indicating that although students are aware of the value of statistics in their daily and professional life, they think it is a difficult subject. It should be noted that the statistics course included no theoretical demonstrations, so the low value in the component *Difficulty* could be due to their perception of a low ability to handle a mathematical formula as students would be perceiving statistics as a branch of mathematics. On the other hand, the students of these courses addressed stochastic concepts for the first time, based on the idea of variability, while Mathematics has been a subject present throughout the different stages of their previous academic life and students have been instructed in deterministic ideas only.

We consider that the greatest limitation of the present study was the number of surveys completed by the students at the beginning (436 students) and at the end of the course (246 students). This may have been due to the fact that some of the students were absent on the days they were to answer the survey, or due to the high dropout rate of the students after the first formal exam of the subject. It should be added that both surveys were answered voluntarily by all the students present.

At the end of the course, an improvement in attitudes was achieved for each component, except for *Cognitive Competence*. This component refers to students' perception of having no difficulty in understanding statistical concepts based on their way of thinking.

Comparing our results with those obtained by other authors (Kerby & Wroughton, 2017), the only substantial difference was in the sign of the component *Value*. Our students showed a significant increase in the values of this component. We believe that the components *Affect* and *Value* were easily improved throughout the courses due to the characteristics of the problems analyzed in class, based on applications in the students' areas of interest.

In agreement with that found in other studies (Hilton et al., 2004; Dempster & McCorry, 2009; Zhang et al., 2012), we found the highest level of correlation between ∆Affect and ∆Cognitive Competence. These two components, although different, represent constructs of highly related attitudes (Chiesi & Primi, 2009). Students who were able to better understand statistical concepts and ideas by incorporating them into their way of thinking had an improvement in the component *Affect*. Since we cannot claim that there is a cause and effect between these two components, from another point of view, one can think that the improvement in the component *Affect* allowed students to incorporate statistical ideas and concepts in greater depth into their thinking.

Unlike that detected in the other components, the improvement in the component *Difficulty* was not related to the students' final performance category. We believe that this result may be due to the fact that the approach given to the courses was applied to the field of empirical research in which students were enrolled and involved minimal use of mathematical tools.

It is noteworthy that the only component that separated the three final students' performance categories in the expected order was *Cognitive Competence*. This result confirmed that the students' scores are consistent with their perception of the understanding of statistical concepts. This finding in the improvement of this component would go unnoticed if we had ignored the students' final performance category. Students who failed the course differed from the rest in the fact that they developed more negative statistical feelings or emotions at the end of the course. The challenge for the teacher is thus to identify that group of students during the course, and attempt to modify those emotions by maintaining a more personalized relationship with them.

Students who passed the course without having to sit for a final exam increased the value given to statistics. To improve this attitude in the rest of the course, we propose to look for activities that show that statistical concepts may be involved in everyday situations or in their future lives as professionals.

We agree with Bayer (2016), who demonstrated that teacher-led project-based learning when the student participates with an active role improves attitudes towards statistics and academic performance. We also agree with Carlson and Winquist (2011) that learning based on activities with students' participation is effective to the extent that these activities encourage them to think about the underlying statistical concepts. In this sense, in a previous work (López et al., 2018), we described our experience in which students participated with an active role in the design and analysis of an agricultural experiment in which it was sought to strengthen the understanding of the concept of the estimator variability. In that experience, we proposed students to assume the role of professionals hired to carry out a whole agricultural experiment (from the beginning to the end and conclusions of it). Since students had their own randomization patterns, which were different from those of their classmates, different final results were expected. In this way, we tried to introduce the idea that, although students had to conclude from their unique randomization, this was only one of all possible randomizations, some of which were presented by their peers. We agree with De Backer et al. (2015) that conceptual discussions between peers and knowledge sharing can help to understand the ideas behind statistical methods and in the learning process.

Teachers should pay attention to their students' attitudes towards statistics. Courses must be nice, not frustrating, less scary, and more effective for students. To encourage students to learn and use statistics, teachers should do everything they can to make teaching and learning more interesting and relate concepts to the daily life and field of study of students (Ashaari et al., 2011). In this sense, Ramírez et al. (2012) expressed that “People forget what they do not use. But attitudes “stick.” Positive attitudes keep us using what we have learned. They also encourage us to look for opportunities to learn more. It is for these reasons that we believe that students’ attitudes are the most important and influential outcome of statistics introductory courses” (p. 67).

One of the challenges for university-level statistics teachers, beyond the specific outcome of the course, is to provide a lasting basis of statistical concepts to students who will not necessarily become statisticians, but who will need to understand and use statistical methods in their professional lives. In this work, we focused on students’ attitudes towards statistics, and we think that the search for an improvement in this regard can guide us to achieve this goal.

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