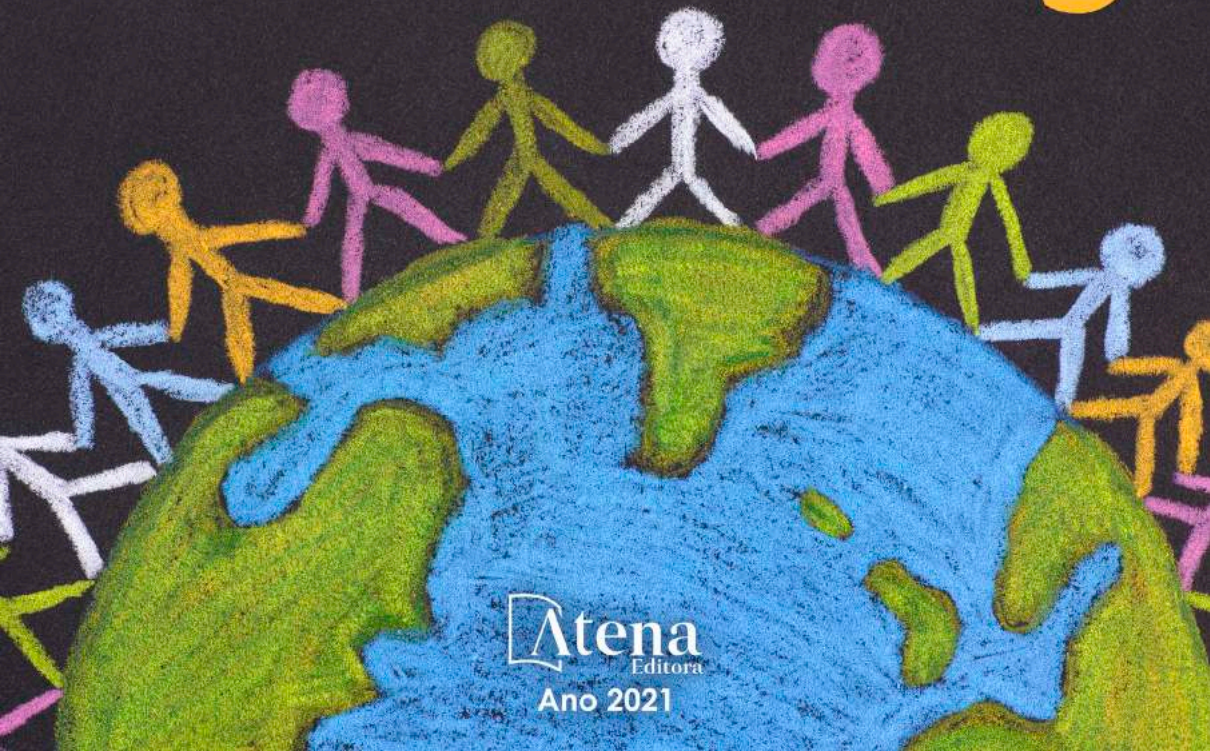
AMÉRICO JUNIOR NUNES DA SILVA
(Organizador)

Educação

enquanto fenômeno social:

Democracia e emancipação humana

5



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APRESENTAÇÃO

Diante do atual cenário educacional brasileiro, resultado de constantes ataques deferidos ao longo da história, faz-se pertinente colocar no centro da discussão as diferentes questões educacionais, valorizando formas particulares de fazer ciência. Direcionar e ampliar o olhar em busca de soluções para os inúmeros problemas educacionais postos pela contemporaneidade é um desafio, aceito por muitos professores pesquisadores.

A área de Humanas e, sobretudo, a Educação, vem sofrendo destrato constante nos últimos anos, principalmente no que tange ao valorizar a sua produção científica. O cenário político de descuido e destrato com as questões educacionais, vivenciado recentemente e agravado com a pandemia, nos alerta para a necessidade de criação de espaços de resistência. Este livro, intitulado "**Educação enquanto fenômeno social: Democracia e Emancipação Humana**", da forma como se organiza, é um desses lugares: permite-se ouvir, de diferentes formas, a mulher negra, o trabalhador, a juventude rural, os professores em seus diferentes espaços de trabalho, entre outros.

É importante que as inúmeras problemáticas que circunscrevem a Educação, historicamente, sejam postas e discutidas. Precisamos nos permitir ser ouvidos e a criação de canais de comunicação, como este livro, aproxima a comunidade das diversas ações que são vivenciadas no interior da escola e da universidade. Portanto, os diversos capítulos que compõem este livro tornam-se um espaço oportuno de discussão e (re)pensar do campo educacional, considerando os diversos elementos e fatores que o intercruza.

Neste livro, portanto, reúnem-se trabalhos de pesquisa e experiências em diversos espaços, com o intuito de promover um amplo debate acerca das diversas problemáticas que permeiam o contexto educacional, tendo a Educação enquanto fenômeno social importante para o fortalecimento da democracia e emancipação humana.

Os/As autores/as que constroem essa obra são estudantes, professores/as pesquisadores/as, especialistas, mestres/as ou doutores/as e que, muitos/as, partindo de sua práxis, buscam novos olhares a problemáticas cotidianas que os mobilizam. Esse movimento de socializar uma pesquisa ou experiência cria um movimento pendular que, pela mobilização dos/as autores/as e discussões por eles/as empreendidas, mobilizam-se também os/as leitores/as e os/as incentivam a reinventarem os seus fazeres pedagógicos e, consequentemente, a educação brasileira. Nessa direção, portanto, desejamos a todos e a todas uma produtiva e lúdica leitura!

Américo Junior Nunes da Silva

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CAPÍTULO 6

THE TEACHING OF MATHEMATICS THROUGH MICROPROJECTS. A SEMIOTIC ONTOLOGICAL APPROACH FOR SOCIAL SCIENCES

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ABSTRACT: The teaching of mathematics in social sciences, at the UAM-X, has undertaken in recent years the search for new teaching methodologies that allow students to obtain a significant knowledge of them. In this work, we show our first research, using some elements of didactic engineering based on the ontological-semiotic approach to knowledge and mathematical instruction proposed by Godino et. to the. (2014) and an own methodological proposal for the elaboration of research microprojects, which we have been working on since 2015. Godino's proposal, which consists of a family of methodological approaches in the study of learning that takes place in natural classroom contexts, we have added a Piagetian process of knowledge construction, through the development of small research projects (microprojects) on current and contextualized social problems of Mexican society. This combination of ideas has allowed us to teach mathematics through a process of design and analysis of instructional strategies and tools (microprojects) implemented in the classroom, the result of which to evaluate is a small research report prepared by each group of students. In this work, as we already indicated, we will show some results.

KEYWORDS: Mathematics, microprojects, didactic engineering.

1 I INTRODUCTION

The teaching of mathematics in social science degrees implies for the teacher of this discipline a work of continuous innovation in its didactics. That is why we want to show a proposal that allows teaching, but above all learning, in a simple way the various contents of mathematics programs, linking it with the context of social problems that arise in the field of work of these degrees using computing packages such as EXCEL, IBM SPSS, among others. We use the elements of didactic engineering based on the ontological-semiotic approach to knowledge (OSA) and the mathematical

instruction proposed by Godino et. to the. (2014) and an own methodological proposal for the elaboration of research microprojects that we have been working on since 2015.

Design-based research (DBR) - also known as design investigations or design experiments- (Brown, 1992; Kelly, Lesh and Baek, 2008) is a set of methodological proposals for the study of learning, based on learning of a specific knowledge under a context. It uses the design and systematic analysis of instructional strategies and tools, trying to ensure that instructional design and research are interdependent, it being understood that the research includes not only the design phase, but also experimentation in classroom contexts and the evaluation of its results. We are looking for this experimentation not only to remain in the context of the classroom, but we intend to extend it to the context of the problems that arise in a society, or in both, if this is possible.

Since the 1980s, Godino et. to the. (2014) indicate that there was an interest in research based on design and its reflection in mathematics education, as well as the study on didactic engineering (Artigue, 1989; 2011, cited by Godino), which, supported by the Theory of Didactics Situations (Brousseau, 1998, cited by Godino), had been developing important contributions to the learning of this discipline at that time. In 2013, Godino et. to the. (2013) takes up these ideas, and studies, the concordances, and complementarities of these methodological approaches, and proposes a generalized vision of didactic engineering that includes research oriented towards instructional design. We take a good part of this idea from a design research methodology (Kelly, Lesh & Baek, 2008) based on the use of tools from the Ontological-Semiotic Approach (OSA) of mathematical knowledge and instruction (Godino, 2002; Godino , Batanero and Font, 2007) and we combine it with the proposal to develop small research projects (microprojects) in the context of the complex problems that Mexican society presents. This combination allows us to propose a teaching-learning process where mathematics is directly related to a contextualized problem in society, thus building a significant knowledge of them in the social sciences student.

2 | THEORETICAL FRAMEWORK AND METHODOLOGY

For the ontological-semiotic approach to knowledge (OSA), the notions of a system of practices and configuration of objects and processes (Godino et. to the., 2007; Font, Godino and Gallardo, 2013) allow the study of epistemological and cognitive analyzes in didactics of mathematics. They formulated the epistemic (characterization of institutional knowledge) and cognitive (personal knowledge) problem in the following terms (Godino et. to the., 2014):

“What are the institutional mathematical practices, and the configurations of objects and processes activated in those practices, necessary to solve a type of mathematical tasks? (Institutional meaning of reference).

What mathematical practices, objects and processes does the student put into play

to solve a type of mathematical task? (Personal meaning).

What personal practices, objects and processes involved in them, carried out by the student, are valid from the institutional perspective? (Competences, knowledge, understanding of the object by the subject). "

With these epistemic and cognitive tools, a first instructional design can be proposed, relative to the intended process and the rules that condition its development (Godino et. to the., 2014):

"What types of didactic interactions (between students and resources) should be implemented in the instructional processes that are suitable for promoting mathematical learning?

What norms condition the development of instructional processes, how are they established, and can they be changed to optimize mathematical learning? "

These questions are prospective in nature, and must be complemented by others that follow the implementation (retrospective nature), which could generically be stated as: What changes should be introduced in the design and implementation of a mathematical study process to improve his learning? This retrospection is common to all didactic engineering, and, in any educational project that has a cyclical nature. The improvement must be based on both the theoretical basis and the experimental contrast (Godino et. to the., 2014).

Godino et. to the. (2014) propose that, "changes based on an instructional process are necessary [to make them explicit with] didactic principles, which are introduced in the OSA through the notion of didactic suitability (Godino, Contreras & Font, 2006). Suitability is conceived as the global criterion of relevance (adaptation to the teaching project) of an instructional process, whose main empirical indicator is the degree of adaptation between the personal meanings achieved by the [students] and the institutional meanings intended or implemented. The suitability supposes the coherent and balanced articulation of the following partial suitability: epistemic, ecological, cognitive, affective, interactional and mediational".

Godino et. to the. (2014) point out that, "in design-based research three phases are considered (Cobb and Gravemeijer, 2008): 1) planning the experiment, 2) experimentation and 3) retrospective analysis of the data generated in the experiment." Based on them, the teaching-learning of the social sciences at UAM-Xochimilco follows a constructivist Piagetian model that links teaching with research and the dissemination of culture through knowledge modules, and that somehow already includes the stages pointed out by Godino. The main objective of this educational model is to develop in students the ability to contribute to the solution of national problems, fostering their sense of social responsibility and their vocation to serve the community (planning the experiment). The module allows studying a problem of reality in an interdisciplinary way using the scientific method to provide a possible solution to it (UAM, 2003, p.15). In this educational system, the student takes a very active role, since his main tasks are to investigate, question and reason all the time about the object that he

is studying; while the teacher interacts with him, only as a guide and organizer, which allows consolidating the knowledge acquired with this experimentation (stage 2). And finally, the result of this experiment is reviewed in a replication, at the end of the trimester (11 weeks), through a retrospective analysis of these findings (stage 3).

The methodological concepts of the OSA are feasible to apply in the modular system and in the mathematics contents that they include. We have used these concepts to propose a mathematics teaching-learning methodology in social sciences degrees that improves learning in this discipline.

Methodology

This is made up of five stages of knowledge construction, in which the three phases proposed by Godino et. to the. (2014) from a design-based research is included (figure 1). These stages should be applied considering the previous referential frameworks of the students, as well as the topics that constitute the mathematics contents of each of the modules of a degree. This prior knowledge and the knowledge to be acquired with the selected microproject will allow the research teams (3 or 4 students) to study and analyze in each module a problem of reality that interests them and that affects the society studied.

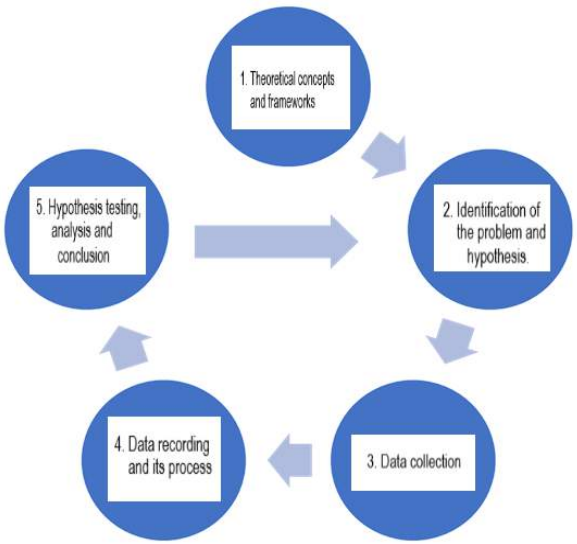


Figure 1

We define a research microproject as a brief investigation on a social problem that can be addressed in 10 weeks and that includes mathematics as part of the analysis and / or solution. As examples of some problems studied by the research teams in the Statistics and Statistical Inference courses, we show the titles of some reports of these investigations:

Rueda G. et. to the. (2015), The importance of labels in transgenic foods.

Ibañez H. et. to the. (2015), Flood problem in Los Reyes, La Paz, State of Mexico, Mexico.

Jiménez J. et. to the. (2016), An analysis of abstentionism in the 2015 elections in Mexico City.

Rojas D. et. to the. (2016), Analysis of the Route 70 service: Azteca-Ajusco Stadium in Mexico City.

Alarcón C. et. to the. (2017), Public security in the El Molino Tezonco neighborhood, Iztapalapa, Mexico City.

Bonfil K. et. to the. (2017), The lack of drinking water in the Iztapalapa delegation of Mexico City.

As can be seen, many of them must be limited to the indicated research period (11 weeks of class), since otherwise, they could not be studied due to the complexity they present.

To show this methodology using the OSA phases, we have selected the theme of Analysis of Variance (ANOVA) of a single factor applied to the problem of comparing the amount of garbage collection (tons) in three neighborhoods near the university.

Phase 1 planning the experiment

The research team determines the study problem, the research hypothesis, the frames of reference and the mathematical tool or tools to be used for its analysis and a possible solution to it. The teacher in this phase specifies and guides the investigation.

The problem

The research team wishes to test the hypothesis that garbage collection (tons / day) in three neighborhoods near the university (Coyoacán, Tlalpan and Xochimilco) is similar, so public resources should be similar (budget, collection trucks, employees, among others). To test this, 8 neighborhood areas that report daily high levels of garbage collection (organic and inorganic) are selected from each neighborhood.

This is a problem with three samples in which the student must prove that there is no difference in the daily garbage collection between these neighborhoods in Mexico City. To test their research hypothesis, the team requires a single-factor Analysis of Variance (ANOVA) statistical test. This test allows testing the significance of the differences between three or more sample means with the data obtained from samples of these populations.

Students must state the research hypotheses.

H_0: $\mu_1 = \mu_2 = \mu_3$ There is no difference between the average daily garbage collection between these neighborhoods.

H_1: $\mu_1 \neq \mu_2 \neq \mu_3$ There is a difference between the average daily garbage collection between these neighborhoods.

The steps of the Analysis of Variance (ANOVA) are applied.

1. Determine an estimate of the population variance between the sample means. In

statistical language, this estimate is known as the variance between columns.

variance between columns

$$\hat{\sigma}_C^2 = \frac{\sum n_i(\overline{X_i} - \overline{\overline{X}})^2}{k-1}$$

2. Estimation of the variance of the population, based on the variance within the samples. In statistical language this variance is called the variance within columns.

variance within columns

$$\hat{\sigma}_{DC}^2 = \sum (\frac{n_j - 1}{n_T - k}) S_j^2$$

3. The two variances calculated are compared (F statistic).

$$F = \frac{\text{variance between columns}}{\text{variance within columns}} = \frac{\hat{\sigma}_C^2}{\hat{\sigma}_{DC}^2}$$

If this quotient is equal to or very close to 1, the null hypothesis is true, otherwise it must be rejected. The F distribution is a family of distributions that are identified by a couple of degrees of freedom unlike the t and Chi-square distributions. The first quantity refers to the degrees of freedom of the numerator of the quotient, while the second refers to the denominator.

Phase 2 experimentation

With the data from the study problem (Table 1), each participant must perform the analysis of variance (ANOVA) manually, using a calculator, pencil, and paper. This allows you to assimilate mathematical knowledge and its calculation procedure. These results can then be compared within the research team. The teacher ensures that this stage of experimentation is carried out individually.

1. Delegación
(toneladas de basura por día)

Colonia	Coyoacán	Tlalpan	Xochimilco
1	11	13	16
2	14	14	15
3	14	12	10
4	10	14	12
5	13	15	10
6	10	14	15
7	10	10	16
8	13	11	16

Once the research team understands the mathematical procedure, it will be able to carry out this same procedure in the next stage with the help of statistical packages or electronic spreadsheets.

The data are captured in the statistical package to be used and the statistical tests of the problem hypotheses are carried out. For the problem in this example, the factor and sample values are captured in IBM SPSS, as shown in Figure 2.

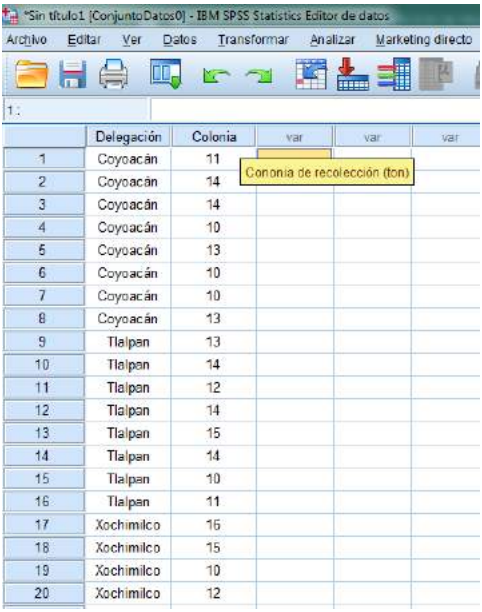


Figure 2

The one-way ANOVA routine is requested as follows: Analyze -> Compare means -> One-way ANOVA (Figure 3).

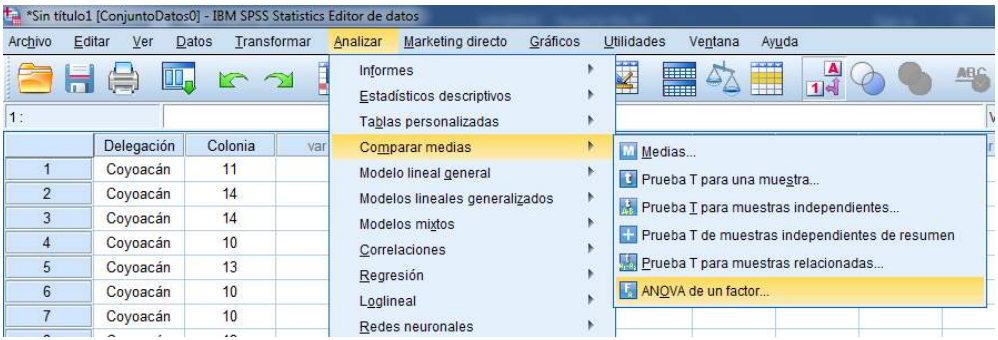


Figure 3

The results of the hypothesis test are obtained and interpreted (Figure 4). In the proposed example, the significance is: α = 0.05. With it we observe the following result:

ANOVA

Colonias - recolección (ton)

	Suma de cuadrados	gl	Media cuadrática	F	Sig.
Entre grupos	14.083	2	7.042	1.586	.228
Dentro de grupos	93.250	21	4.440		
Total	107.333	23			

Figure 4

Since the statistic p (Sig.)> 0.05 (.228> 0.05), then we must accept H_0. This indicates to the research team that there is no difference in daily garbage collection between these neighborhoods. The average collection is similar.

One-way ANOVA with EXCEL

First, we capture the data of the problem (table 1) in a spreadsheet. Second, from the Menu: DATA, select DATA ANALYSIS. And in this one, select: Anova: Single Factor (figure 5).

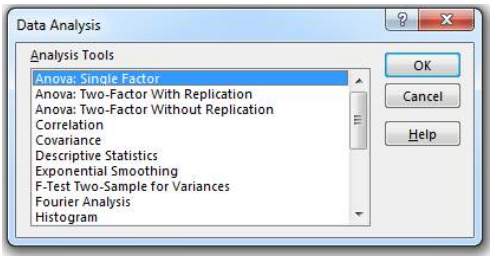


Figure 5

The result of the requested analysis is obtained and interpreted.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Coyoacán	8	95	11.88	3.2679
Tlalpan	8	103	12.88	2.9821
Xochimilco	8	110	13.75	7.0714

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	14.08	2	7.0417	1.586	0.228	3.467
Within Groups	93.25	21	4.4405			
Total	107.33	23				

Since the F statistic is in the acceptance zone F < Fcrit, we must accept the null hypothesis, as we had already determined with the calculation of the IBM SPSS package.

Using two packages, one specialized and the other widely used, allows the student to have two computational tools for statistical analysis, which makes their practical knowledge more flexible.

Phase 3 retrospective analysis of the experiment

Some observations from this analysis are:

- Greater participation (attendance) is observed in math class.
- Doubts and questions about the projects are solved in class with the participation of the research teams.
- The student uses the previous mathematical frameworks (ratios, proportions, percentages, measures of central tendency (arithmetic mean, median, mode), measures of dispersion (standard deviation, variance), probability distributions (F).
- There is greater appropriation of the knowledge of statistics and the management of the computer packages used (EXCEL and IBM SPSS).
- A direct application - in the field - of the mathematical knowledge acquired in the classroom is observed by the speaker.
- Failure levels decrease.
- There is agreement with Piaget's teaching-learning ideas applied in the UAM-X and OSA proposed by Godino et. to the. (2014).
- It has been an experience that we suggest replicate.
- The learning of mathematics appears to be significant in social sciences student.

3 | FIRST RESULTS

We have applied the proposed methodology in two groups of inferential statistics for the fall quarter of 2017 (September - December). The results of this application are compared with the ratings obtained with two groups from the same quarter of 2016, in which this methodology had not been applied. The value of the course is 25 points, with a minimum accreditation score of 15 points.

The statistical table below shows the results for these groups.

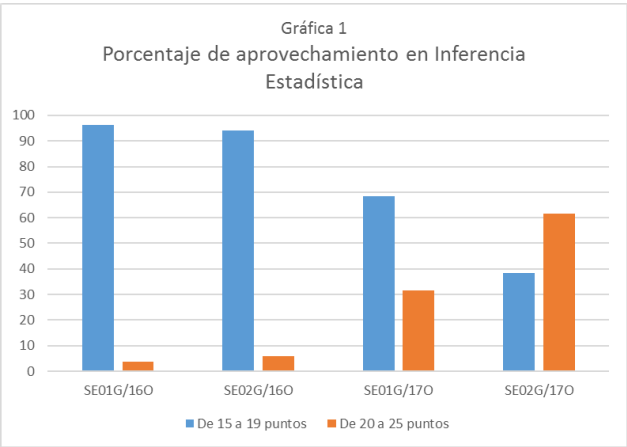
Evaluación final del curso de Inferencia Estadística

Concepto	Grupo/trimestre SE01G/16O (alumnos)	%	SE02G/16O (alumnos)	%	SE01G/17O (alumnos)	%	SE02G/17O (alumnos)	%
Total de alumnos	28		28		21		19	
Alumnos acreditados con:								
De 15 a 19 puntos	26	96	16	94	13	68	5	38
De 20 a 25 puntos	1	4	1	6	6	32	8	62
Alumnos no acreditados	1	4	11	39	2	10	6	32

Fuente: Elaboración propia con datos de los grupos.

A significant advance in math learning. In the SE01G group of autumn 2016, it was observed that 96% of the students obtained scores between 15 and 19 points and only 4% between 20 and 25 points. That same group a year later in which the proposed teaching methodology was applied, a decrease of 28% in scores is obtained from 15 to 19 points (68%), and a similar increase in scores ranging from 20 to 25 points. For the SE02G group, a 56% decrease is observed in the scores from 15 to 19 points and a similar increase in the scores from 20 to 25 points. Apparently, the proposed methodology improves math learning and its quality, since students obtain higher scores. However, the percentages of non-accreditation of the course seem to increase in the case of the SE01G group - from 4% to 10% - and decrease very little in the case of the SE02G group - from 39% to 32% -.

Graph 1 shows this apparent quality improvement in the learning of the statistical inference groups of the Bachelor of Politics and Social Management. Remember that the proposed methodology was not applied in the groups for the fall 2016 quarter. Therefore, we consider that the significant learning -higher scores- in the student when applying this methodology increases considerably. The only thing left for us is to continue testing and improving the teaching-learning of mathematics at the university level in social sciences.



Graph 1

4 | OBSERVATIONS AND REFLECTIONS

- The proposed methodology follows the basic guidelines of the scientific method, so the first results obtained to date are very encouraging for the teaching of mathematics in social sciences.
- The university student becomes the main actor when investigate, analyze, and propose the statistical tool that allows him to solve a problem of reality. For this reason, he is forced to know and properly operate the statistical tools necessary for each problem.
- The student appropriates knowledge as he accepts a real problem as a challenge.
- The work of the teacher in the classroom becomes a guide to bring the student closer to applied mathematical knowledge.
- When evaluating this methodology, we have limited ourselves to only one variable (learning mathematics), so it remains to study this educational process with other variables that may be significant.
- This methodology apparently improves the quality - at least in numbers - of learning. However, as we have already indicated, other variables are required to verify this first statement.
- We intend to continue experimenting with this methodology, to perhaps find a new path that facilitates the teaching-learning process of mathematics in social sciences.

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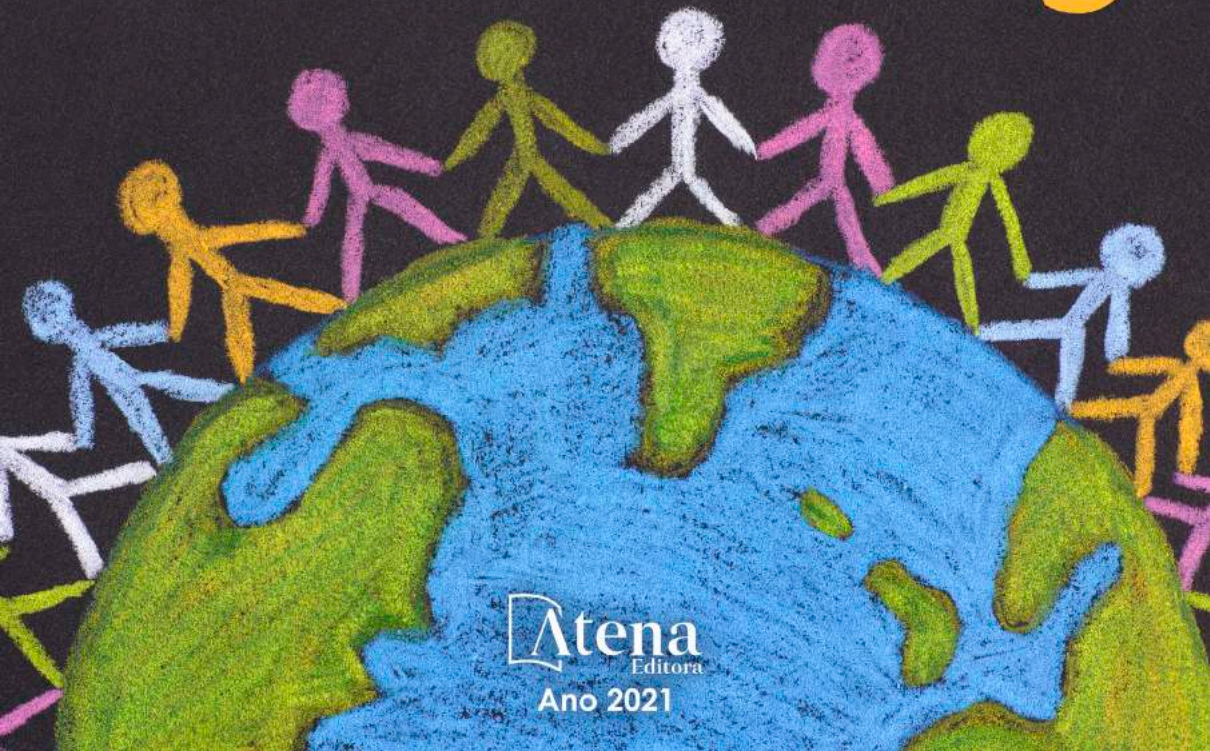

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