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TEACHING OF ANOVA THROUGH A RESEARCH PROJECT

ENSEÑANZA DE ANOVA A TRAVÉS DE UN PROYECTO DE INVESTIGACIÓN

ANÁLISE DA ANOVA POR MEIO DE UM PROJETO DE INVESTIGAÇÃO

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Abstract
Statistics plays an important role in curricula, not only for university education, but also for middle and high school education. The changes that have occurred in recent years in the field of science and technology have generated a constant modernization of education; therefore, it becomes necessary for teachers to apply new didactic strategies that allow students to develop their learning processes. In this sense, the teaching of Statistics through research projects stands as one of the most appropriate pedagogical proposals for such purposes. Under this premise, the teachers in charge of the Statistics course of Licenciatura en Nutrición, Bioquímica and Licenciatura en Biotecnología from the Facultad de Bioquímica y Ciencias Biológicas de la Universidad Nacional del Litoral, Santa Fe, Argentina, proposed to address the content analysis of variance (ANOVA) under this methodology in order to analyze its impact. Teachers of Statistics courses worked with students from the Licenciatura en Nutrición, Licenciatura en Biotecnología y Bioquímica that attended Statistics course in 2018. After implementing the strategy, the students had to submit a report on the development and resolution of the proposed project. A statistically significant difference was observed between the group of students evaluated with this methodology in relation to those students evaluated in previous years where it was not applied. According to the observed results, it can be infered that the strategy would have a favorable action in the teaching-learning process of the topic, at least in those careers focused on health, biology or technique.

Key words: ANOVA; teaching by projects; problem solving.

Resumen
La Estadística juega un papel importante en los currículums, no solo de formación universitaria, sino también secundaria. Los cambios ocurridos en los últimos años en el ámbito de las ciencias y

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tecnologías, han generado una constante modernización de la educación; por lo que se torna necesario que los docentes apliquen nuevas estrategias didácticas que permitan desarrollar los procesos de aprendizaje de los estudiantes. En este sentido la enseñanza de la Estadística por proyectos de investigación se erige como una de las propuestas pedagógicas más apropiada para tales fines. Bajo esta premisa, los docentes a cargo de la asignatura Estadística de las carreras Licenciatura en Nutrición, Bioquímica y Licenciatura en Biotecnología de la Facultad de Bioquímica y Ciencias Biológicas de la Universidad Nacional del Litoral, propusimos abordar el contenido: análisis de la varianza (ANOVA) bajo esta metodología con el objetivo de analizar su impacto. Se trabajó con alumnos de las carreras: Licenciatura en Biotecnología, Licenciatura en Nutrición y Bioquímica que cursaron Estadística en el año 2018. Luego de implementada la estrategia, los alumnos debían entregar un informe relativo al desarrollo y resolución del proyecto propuesto. Se observó una diferencia estadísticamente significativa entre el grupo de alumnos evaluados con esta metodología en relación con los evaluados de años anteriores en donde no fue aplicada. De acuerdo a los resultados observados, podemos inferir que la estrategia tendría una acción favorable en el proceso de la enseñanza aprendizaje del tema, al menos en aquellas carreras con orientación en salud, biología o técnica.

Palabras clave: ANOVA; enseñanza por proyectos; resolución de problemas.

Resumo
A estatística desempenha um papel importante nos currículos, não apenas no ensino universitário, mas também no ensino médio. As mudanças que ocorreram nos últimos anos no campo da ciência e da tecnologia geraram uma constante modernização da educação; portanto, torna-se necessário que os professores apliquem novas estratégias didáticas que permitam aos alunos desenvolver seus processos de aprendizagem. Nesse sentido, o ensino de Estatística por meio de projetos de pesquisa se destaca como uma das propostas pedagógicas mais apropriadas para tais fins. Sob essa premissa, os professores responsáveis pelo curso de Estatística dos cursos de graduação em Nutrição, Bioquímica e Biotecnologia da Faculdad de Bioquímica e Ciencias Biológicas da Universidad Nacional del Litoral, propuseram abordar o conteúdo análise de variância (ANOVA) sob essa metodologia para analisar seu impacto. Trabalharam com estudantes dos cursos: Biotecnologia, Nutrição e Bioquímica, que cursaram Estatística em 2018. Após a implementação da estratégia, os alunos tiveram que enviar um relatório sobre o desenvolvimento e a resolução do projeto proposto. Observou-se diferença estatística entre o grupo de alunos avaliados com essa metodologia em relação aos avaliados nos anos anteriores quando não foi aplicada a estratégia avaliada. De acordo com os resultados observados, podemos inferir que a estratégia teria favoreceu o processo de ensino-aprendizagem do tópico, pelo menos nas carreiras voltadas à saúde, biologia ou técnica.

Palavras-chave: ANOVA; ensino por projetos; resolução de problemas.

Introducción

There is an implicit consensus in the field of educators to generate a statistical culture in society, which has been growing for about three decades, approximately, leading to the fact that, at present, Statistics plays an important role in the curricula of all levels. This is due to the fact that its applications extend to almost all areas of

knowledge, since it provides methodological tools that allow the development of competencies for data collection, variability analysis, generation of predictions and decision-making in situations of uncertainty, also enabling developing many cognitive skills (SALCEDO, 2013).

The massive incorporation of this discipline in almost all university career plans poses a didactic challenge when its teaching aims to convey the "statistical sense" (BATANERO, DÍAZ, CONTRERAS Y ROA, 2013) that amalgamates culture and statistical reasoning. Considering statistical culture as that of knowing the fundamental ideas necessary in most applied situations and for which Watson (2006, mentioned by BATANERO et al (2013) indicates that its essential elements for acquiring it are: development of basic knowledge of concepts, understanding of their reasoning and arguments in a broader context and with a critical attitude towards statistical evidence.

In the experimental, social and health sciences, among other specific non-mathematical sciences, many statistical elements are used in research that allow us to analyze, interpret and conclude regarding their problems; therefore, the Statistics that are taught in these areas require that it be adapted for these purposes; pursuing as an objective that the concepts are learned significantly so that they provide the subject with a decisive tool for both professional performance and daily life.

On the other hand, university education has been going through a moment of transformation, as well as searching for a new sense of knowledge urged not only by the demand for quality but also for results. The changes that have occurred in the field of science and technology have generated a constant modernization of education; so it becomes necessary that the teachers apply new didactic strategies that allow to develop the learning processes of the students, to promote the critical sense and the functional application of the specific disciplinary concepts; promoting, in addition, an articulated vision that contributes to acquiring meaningful learning of the contents of all the disciplines involved (ZEMELMAN, 1998).

Paradoxically, despite the passing of an era of information and technology, students still continue to learn concepts in a rote way, focusing their learning on mathematical calculations, the elaboration of tables and graphs, being a challenge to achieve

the ultimate goal of teaching Statistics, which is the analysis and interpretation of the information.

In this sense, the concern of teaching teams to improve the efficiency of their tasks is increasingly evident, surely due to the suspicion that traditional forms are not giving the expected results (BEHAR, 2001).

In the particular case of Statistics applied to biology and health, its teaching is generally unrelated to the problems pertinent to the professional practices of the students, which generates demotivation and a lack of commitment to learning. To address this situation, efforts should focus on designing contextualized teaching proposals, according to the area of specialization of the students, that enable them to face real problems, solve them reliably and scientifically argue the conclusions.

In this sense, those methodologies that aim to articulate both vertically and horizontally the disciplinary contents with other areas of knowledge, particularly those specific to the profession, that give meaning to the contents addressed would be relevant to be retrieved in subsequent instances.

Thus, the teaching of Statistics through research projects stands as one of the most appropriate pedagogical proposals for such purposes (BATANERO, 2017); given that it promotes the study of concepts in a more circumscribed way, encouraging reflection, motivated by their vocational affinity (BENDER, W. 2014), helping to develop critical reasoning based on the evaluation of objective evidence (OTTAVIANI, 1998) and personally satisfying the desire to learn (SÁNCHEZ, 2013). At the same time, López and Chávez (2012), Martínez and Cano (2014) consider that teaching by research projects, by implying the approach of a problem of the professional disciplinary context, grants multiple competences to the graduate's profile; since they expose realities with a multiplicity of variables that need to be studied with the contributions of the knowledge of the different branches of knowledge, providing the appropriate tools for the comprehensive training of the future professional (SULBARAN, 2017) and contributes to the significant learning of the proposed objects (BATANERO, 2001).

In this line, Isaza et al. (2005) and Zemelman (1998) affirm that the freedom to ask, discuss, criticize and dissent, gives an articulated vision that contributes to forge meaningful learning in all the disciplines involved. Since, according to Ausubel

(1963), this is the process through which new information is related in a non-arbitrary and substantive way to the cognitive structure of the person who learns.

In turn, the development of research projects imposes the use of current technologies; In this case, it is necessary to learn skills in the usage of statistical computer programs that favor the integration of the subject into an increasingly computerized society (CABERO ALMENARA, 2007).

Under the premise that educating through research projects fosters the integrative and functional sense and culture of statistics, the teachers in charge of the Statistics course of Licenciatura en Nutrición, Bioquímica y Licenciatura en Biotecnología from the Facultad de Bioquímica y Cienicas Biológicas of Universidad Nacional del Litoral, proposed - as a starting point to follow this path of trying to improve the quality of the educational process - to address the content analysis of variance (ANOVA), through real problematic situations, formulated as a project of research with an interdisciplinary approach.

ANOVA is a subject that has multiple applications in different areas, particularly in the health sciences. This technique allows determining the effect that the different levels of some factor have on some response variable. In this proposal, the ANOVA was used with a completely randomized design, which is the simplest case of this methodology (MONTGOMERY, 2004).

Thus, this research aims to analyze the impact on student learning of the ANOVA topic through real problems formulated as research projects.

It is worth mentioning that this proposal was framed in the activities plan for the Statistics area, in the Research Project: PI50120150100053LI "Educación Matemática e interdisciplinariedad". Eje Principal de trabajo: "la modelización", financed by the Universidad Nacional del Litoral- Santa Fe- Argentina.

Methodology

We worked with students from the careers Licenciatura en Nutrición, Bioquímica y Licenciatura en Biotecnología that asisted to en Statistics coursein 2018. This course is inserted in the second year of the study plans of the three careers mentioned above, with the same thematic program that includes descriptive, probabilistic,

modeling (simple linear regression) and inferential statistical concepts. This last area includes, en first place, the parametric and non-parametric hypothesis tests, comparing one or two means or proportions, goodness of fit to normality and the relationship between categorical variables, and then, in the framework of the área of Experimental designs, one-way ANOVA with fixed effect.

The course includes theoretical classes and practical work in conventional classrooms in which exercises related to the theoretical topic addressed under different activities of conceptual development, procedural calculations, use of specific software, etc. are solved. Starting in 2018, classes were incorporated into the computer laboratory in which the usage and applicability of area-specific programs such as SPSS and Infostat are taught.

All activities are mandatory. In order to achieve the condition of regular or directly promoted student, it was required, among other issues, to carry out the research project included in the report of this paper.

The proposal was carried out in two stages. The first consisted of a theoretical-practical class where the basic contents of the ANOVA topic of a factor with a fixed effect were developed. At this point class notes and bibliographic material were provided. The presentation of the topic was developed from a problem situation contextualized in an area of interest for the students; situation that was used as a trigger for the need to use a new statistical methodology for when there is a need to make comparisons among more than two samples. This allowed the theoretical contents, their application and interpretation in the context of the problem posed, to be worked on throughout the class.

In the second stage, students were encouraged to form groups of at least five people. Different themes related to their career were proposed to them, from which each group had to answer a problem question formulated on a chosen topic, by preparing a "research project"with a general same work structure, for all the students, accompanied by relevant scientific bibliography. At this point, they were given a practical guide to carry out bibliographic searches of scientific articles to support their conclusions and they had to compare their conclusiones with those obtained by other authors on the same subject.

The objectives that were proposed in each topic of work were feasible to solve in their student context, attentive to their possibilities (taking into account that they are in the second year of the degree) and level of scientific knowledge in the discipline.

Each group of students had a tutor teacher, in charge of monitoring the development of the projects, answering their questions and clearing all their doubts, collaborating with the students in different aspects such as: the design of the instrument to collect both qualitative and quantitative variables; the critical reading of the collected bibliography on the subject; the assurence the methodological coherence of the project, that is, if the sample design, the instrument, the objectives are consistent with the applied inferential methods, among others aspects.The tutor teacher coordinated weekly meetings (extra to the usual office hours) to discuss possible actions for the development of the activity. Following a plan designed for the occasion, we sought to promote that the projects allow applying a complete statistical analysis of the technique in question by using one of the following computer programs: SPSS or Infostat.

After the time established for the submition of the project, the members of the different groups had to submit a report regarding its development and resolution, arguing their methodological procedures and conclusions;also, and as an ending work of the proposal, they had to do en oral presentation of it for the rest of the students and teaching team.

To assess whether this didactic strategy could collaborate in learning about the subject in students, the proportions of students who correctly solved the ANOVA exercise applied in the middterm taken in 2017 were compared to those results obtained in 2018. In 2017 the didactic strategy was different. In this year classes were carried out exclusively in classrooms without the use or management of computer programs to solve problems. A test of proportions difference was used. The project reports were also evaluated, regarding the functionality of the conclusions they reached in terms of the objectives set out in the study.

The applied exercises presented in the questions of the midterm exams -for the direct promotion of the subject in the attending students- corresponding to the ANOVA topic were for the year 2017:

> *"A research team is interested in evaluating the protein content reported by four brands of cereal bars. To do this, it was designed a*

> *completely randomized experiment with the objective of verifying if the average protein content of the cereal bars of the four brands could be considered equal. When processing the obtained data using the ANOVA technique, the following results were observed. (Results of outputs generated by the InfoStat program are shown).*
> *5.1. State the null and alternative hypothesis of the problem.*
> *5.2. Is it possible to consider that the average protein concentrations in the four brands of cereal bars are the same? Properly justify your answer with what is offered in the results tables.*
> *5.3. If concentrations are not considered equal, are they all different from each other? Properly justify your answer with what is offered in the results tables.*
> *5.4. In order to use the statistical technique you used to answer the previous question, what assumptions must be satisfied? List them and use the software outputs to justify your answer.*
> *5.5. What was the final conclusion of the research?"*

And for the year 2018:

> *"In a research, a completely randomized experiment is designed in order to analyze whether it is possible to consider that the average calcium concentration of yogurts, commercially similar, but from four different brands, is the same. When processing the obtained data using the ANOVA technique, the following results were observed. (Results of outputs generated by the InfoStat program are shown).*
> *5.1. State the null and alternative hypothesis of the problem.*
> *5.2. Is it possible to consider that the average calcium concentrations in the four brands are the same? Properly justify your answer with what is offered in the results tables.*
> *5.3. If the concentrations could not be considered equal, are they all different from each other? Properly justify your answer with what is offered in the results tables.*
> *5.4. In order to use the statistical technique you used to answer the previous question, what assumptions must be satisfied? List them and use the software outputs to justify your answer.*
> *5.5. What was the final conclusion of the research? "*

In particular, the answers of the students to sections 5.2, 5.3 and 5.5, allow observing the ability to understand functionally the way to proceed in order to achieve and respond to a study objective, interpret the results shown by the outputs of a Statistical program when applying the appropriate resolution technique and the arguments of a justification.

In relation to the answers for the case of subsection 5.2, the student's affirmation or denial of this question was taken into account, on the one hand, and how it was justified on the other.

For item 5.5, it was analyzed whether the answer was expressed correctly or not, in terms of the problem posed.

For the quantitative approach, analyzes were carried out in SPSS 22.0 (SPSS Inc., Chicago, IL) or Infostat, with a significance level of 0.05.

Results

The proportions of students who correctly answered and justified sections 5.2 and 5.3 of the proposed exercise in the midterm exam of the year 2018 (in which the didactic strategy object of this paper was implemented) turned out to be significantly different from those of the previous year, when ANOVA was taught in the traditional way (p values <0.05); in this sense, students showed a better interpretation of the results that appear in the outputs of the statistical program, that is, they were able to take the correct decision to asume that not all the means of calcium concentrations in yogurts are the same. They also showed a better interpretation of the posteriori tests for identify which one or which differ from each other. Results show that 18% of the students selected or misinterpreted these conclusive values. The remaining 3% did not respond.

A similar analysis was carried out with the answers to subsection 5.5, and the proportions of students between the years 2017 and 2018 turned out to be quite different in their conclusion alluding to the objective of the project and in terms of the real problem.

It can be seen that carrying out collaborative research project for the learning of ANOVA, on the other hand, was essential for the development of different skills and capacities that make the interpretation and analysis of the subject in greater depth.

In this sense, in each of the project stages, it can be seen that students made the exercise of avoiding obstacles and going through the challenge of contextualized work with real data. Among them, the difficulty of formulating a clearly defined problem; the recognition and classification of the variables; the collection of data adequately so that they are reliable and allow decision-making; the exercise of summarizing databases through the construction of appropriately selected graphs or tables through trial and error, and that allowed to show the obtained results in the most appropriate way;the fact of considering the possibility of transmitting biased information in a poorly constructed graph or a poorly applied statistical technique; the challenge of interpreting outliers; the understanding of the variability of the data and the uncertainty generated by

unexplained variability; the usage of Information and communications techniques (TIC); the exercise of preparing reports, of orally presenting the topic, which required a deep interpretation of the project, among many other skills.

Although the acquisition of these skills is not within the objectives of this research, being unable to show results in this regard, it can be seen that these skills were necessarily developed and put into practice, in order to achieve the observed results.

Conclusions

First of all, it can be said that teaching ANOVA through a research project, with the use of new technologies combined with traditional classes, helped teachers to approach their concepts in a more dynamic way and in consistent with Murray and Gal (2002), this methodology promoted understanding, interpretation and a positive reaction towards Statistics in general. Also, the acquisition of other skills such as linguistics, teamwork, argumentative report writing, bibliographic search, discernment of the context, ability to ask questions and a critical posture supported by a set of beliefs and attitudes were observed in the students. Likewise, the emphasis on interdisciplinarity that was carried out contributed to the learning gaining in significance and functionality.

This methodological change implied greater demand from students to the teacher, since it is the first time that students carry out aproject of this type in their career. This demand translated into a greater time of teaching dedication to the subject, both face-to-face and virtual due to the continuous monitoring of the project. This follow-up showed that learning construction was achieved at different levels and times among the project teams, but all progressively, as they were able to complement the theory, practical training, and completion of the developed project, which was made visible in each of the submitting sand meetings with the groups.

Looking at the observed results, we can infer that the strategy would have a favorable action in the teaching-learning process of the topic, at least in those careers with a health, biological or technical orientation.

On the other hand, this methodology has given both students and teachers the possibility of learning the need to interact with other sciences and actors from different disciplines to specify the construction of a knowledge object.

We know that the challenges of statistical education are complex and multiply in the context of vocational training, but the opportunity lies in being able to take advantage of the situations specific to the practice of each profession as a source to promote meaningful learning of its concepts. This implies joining efforts both with the teachers of this subject and with those of the main disciplines of the careers.

However, all the mentioned advantages are accompanied by the great effort involved in approaching teaching from an interdisciplinary cooperative perspective, making it impossible to carry out this methodology without a committed team and with the same objectives.

For the achievement of these objectives, the active participation of educators is required, who must act as managers of knowledge and the environment (instruments, situations) so that the student can improve their learning processes.

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