ADVANTAGES OF APPLYING THE PROJECT METHOD TO THE TEACHING OF STATISTICS

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The research-framework is based on the project method, which focuses on learning by working on a project with all steps from defining a task until reaching at a reasonable solution. In Argentina, this method is applied at secondary school. According to the theme chosen by the students, the contents of descriptive statistics and notions of statistical inference are presented. This methodology is motivating to achieve understanding of statistical contents taught and generate new experiences by the teachers in their classes. The proposal is to generalize this method to university education. The following discussion is based on an exploratory teaching experiment carried out in the subject of biostatistics. We report about the project to the research community in statistics education as the results obtained are highly satisfactory and bear a didactic potential to reduce the impact of factors that negatively affect the construction of understanding in the learning processes in statistics.

BACKGROUND

For Batanero and Díaz (2004), statistical projects increase students' motivation and engagement. There is nothing that makes statistics more odious than the resolution of decontextualized exercises where the student is asked to calculate the mean or adjust a regression line to a set of numbers. As Holmes (1997) suggests, several positive points are achieved if students work on statistics through projects:

- The projects allow contextualizing the methods and concepts of statistics and making them more relevant. If data arise from a problem, it is meaningful data and has to be interpreted in the context.
- Projects reinforce and stabilize interest, especially if it is the student who chooses the topic. The student wants to solve problems not imposed by the teacher. This is essential for self-activating processes within the learners and attributes to them a responsibility about the progress of their work.
- One learns better what real data is, and one can face ideas that usually are missing with data invented by the teacher: e.g., precision, variability, reliability, measurement problems up to the level that measurements are not even possible, and bias of measurements.

The projects are conceived as authentic investigations not just faked or pretended questions that no one would be interested or even with no (relevant) question related to tasks that are given to the students. The projects must be chosen carefully, be realistic and appropriate to the level of the student. Projects with real problems may also show the true character of statistical methods that have always been developed in response to problems to solve from the practice. Borovcnik (2018) speaks about the value of project work on applied problems for the conceptual growth of the students and about the challenges of such an approach as it demands a variety of competencies beginning from organizing the work and ending with communication and leadership: the need to communicate and to understand the problem and the methods used and to find suitable answers that bear a significant meaning in the context.

Álvarez (2001) also considers that projects are not a different way of planning; it is a teaching-learning methodology that puts the subject in a better learning situation. He also notes that for the students, the projects are the reason and driving force for their effort and enthusiasm; for the teacher, on the other hand, the projects constitute a methodological tool, an excuse that offers rich and varied teaching-learning possibilities of curricular contents that are very hard to justify or even to motivate in artificial learning environments as it would not become clear what they could stand for and the students would doubt that they could ever be used to solve relevant problems. Instead of introducing decontextualized concepts and techniques, or applied artificial-type problems, difficult to find in real life, it is about presenting the different phases of a statistical investigation: approach to a problem and defining the essential questions that should be analyzed, decision about the data to be collected, collection of the data with all its "dirty" phases of sources of errors, data analysis, and – finally –

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conclusions about the problem raised and integrating the new knowledge into the existing body of knowledge about the context, in which the project topic is embedded.

Batanero (2001) suggests a sequencing of components of a project, which, due to its open nature, could lead to different designs:

- Statistics applications (extensive and intensive elements).
- Concepts and properties (intensive elements).
- Notations and representations (ostensive elements).
- Techniques and procedures (actuative elements).
- Attitudes (validative elements).

FRAMEWORK

The theoretical framework is based on the project method (Batanero, 2001), and the epistemological and cognitive model proposed by the ontosemiotic approach to mathematical cognition (Godino, 2003). A project, in the sense that we understand it, necessarily implies the construction of something concrete, visible, demonstrable, developed and finished in a predetermined time, for which we must acquire, strengthen or exercise certain knowledge and skills and which may question many of our attitudes and procedures. With respect to the secondary school, the project method in Argentina is applied along and across the curriculum covering several subjects according to the thematic chosen by the students, as proposed by Schield (2006).

A project topic may arise from both the teacher and the student or from a need for articulation within the institutional curriculum. The important thing in any of the cases is to keep in mind that it always implies a previous elaboration by the teacher, who is the one who will determine his pedagogical intent. Then, students in groups of three, depending on the theme chosen, present the different contents of descriptive statistics that can be used, the justification of their choice, and the corresponding interpretation depending on the context of the problem situation. The progress and the final results are shared among all students: each group presents the project scheme on the chosen topic, and analyzes a possible didactic trajectory, anticipating all the statistical techniques they will need to use, justifying and arguing their application, and finally reports about their results with a lively discussion where the audience (their peers) is well engaged. Some of the themes covered up to now are: SOS Health; The world cup from multimedia optics; School dropout and sports; How do students of intermediate level use the Internet?; Adolescents faced with addictive substances: tobacco and alcohol; Profile of the top scorer of each soccer world cup; Use of mobile telephones by teenagers; Does wearing a seat belt save lives?

The satisfactory results of this evaluation allow us to consider this methodology as motivating to achieve a good understanding of the statistical contents usually taught within the curricula and generate new experiences of this type by the teachers in their classes as builders of their own teaching materials.

THE DEVELOPMENT OF THE EXPERIENCE

Here we present the implementation of statistics topics in an integrative project of Veterinary Sciences. Our proposal is to generalize the project method in subjects of a first Basic Statistics course, common to different university degrees. It is based on an exploratory experiment carried out in 2018 in the subject Biostatistics at the National University of Rosario (UNR) with 231 pupils, corresponding to the 2018 course, plus 198 students who had already completed the subject but could not regularize it, that is, in total, 329 students participated in our experimental class. This first Biostatistics course is made up of descriptive statistics and notions of inferential statistics. At the beginning of the course, the students were explained the work methodology: the classes would be theoretical-practical, where one weekly hour would be dedicated to the follow-up of the project chosen by each group of three students who would be grouped by affinity to the subject with which they would work.

The didactic trajectory in each project is based on Nolan and Speed (1999) who suggest that in the beginning the teacher should not focus on statistical terminology but provide generic strategies that can be generalized to other data and contexts. A list of points to consider when raising research questions is as follows:

- What is my problem? What do I want to try?
- Do I need data? Which? What do I have to measure or observe or ask?
- How to find the data? What to do with them? How can I get them?
- How to collect the data? Observation, surveys, or planning suitable experiments? What is the relative benefit of the various methods?
- What to do with the data? What methods are suitable to analyze it? What are hidden assumptions of these methods and how do the methods restrict or enable specific questions to be analyzed?
- What do these results mean in practice? What is their significance in relation to the problem posed? What are further problems that arise exactly from the present project?

The projects were carried out from databases provided by other chairs or by livestock farms in the area, according to the interest of the students. All the databases of the students were analyzed to see whether they fulfilled the assumptions to apply all the techniques taught in their investigation. In those cases that lacked data, they were asked to continue with other information that was provided to them from the chairs where they requested the databases. Some related to livestock breeding: weight, number of calves, or characteristics of horse breeds. Others related to histological studies of the pancreas, incorporation of fats in foods used in nutrition of rabbits, effects of supplementation with artichoke extract on the growth of fattening rabbits, risk factors for fertility in the breeding herd, morphometric analysis of porcine pancreas according to breed, effect of the number of previous calvings on pregnant Holstein × Cebu cows and the comparison of the results to the pure breeds. From their databases, the questions already raised should be formulated and the statistical techniques taught in their problematic situations should be applied, the conclusions in terms of the problem being an essential element of the discussion within and across the groups.

This is the key question that gives rise to the understanding of descriptive and inferential statistics issues and the need for their interpretation in terms of the problem and its context. The approval of the project would be a requirement to access the final exam as a regular student. The themes that will be evaluated in the project are the traditional contents of the curriculum: Descriptive statistics, probability, and probability models, brief notions of inference, confidence intervals and hypothesis tests. We consider that the moment that required more time and effort was the choice of the subject and the search for information and data on it since the students had to collect databases in the different chairs of the Faculty, or in research papers provided by other veterinarians. The analysis of the potential themes for the project was carried out with each group and then the thematic units of the course that would be included in the project were divided. For each thematic unit four moments of analysis of the progress of the projects were presented, in this way the errors were corrected jointly with the students of the group through the discussion and argumentation of the steps and procedures performed by the students in the subject. Thus, students were able to overcome their difficulties and continuously improve their proposals.

The argumentation requirements were stressed as it was one of the shortcomings that were anticipated by previous experiences in teaching practice. In addition, to strengthen this capacity, we made a monthly pooling, where each group commented on their work and made a personal reflection on the progress or drawbacks in their project. These moments allowed students to present their ideas, argue about their work, and prepare for the final evaluation of the project. The monthly pooling was evaluated by the students of the group using the didactic metacognition strategy and their opinion was corroborated in most cases by the teacher of each commission. The final presentation of each group was evaluated by all the teachers.

For each project, the evaluation in the process of the didactic trajectory was made in four stages based on the following criteria: the elements of meaning, the topics, and the students grouped according to the project. For the general difficulties that arise from the task of evaluating projects, see also Baca Urbina (2012). The elements of meaning evaluated were: conceptual understanding; procedural understanding; contextualization of the problem; formulation and communication in statistical terminology; validation of what has been done and expression of conclusions in terms of the problem. The topics were: Descriptive statistics with tables and graphs, measurement of tendency, dispersion, and shape. Probability with random variables, and probability models; Basic notions of Inference: point estimation, confidence intervals, and hypothesis tests.

As for the academic performance in terms of regularization of the subject, the relationship between students who attended the subject and students who achieved regularity with the approval of

the project are presented. Of the 231 students who studied Biostatistics for the first time 167 (72%) regularized it, while of the 198 students who attended the course in previous years and could not regularize it, 149 (75%) regularized it now with the project method. The students who did not regularize the subject were those who showed no commitment throughout the development of the project or who were discouraged by the information search work at the beginning. All the projects that continued were successfully substantiated. The change in methodology allowed the students who participated from 1st, 2nd, 3rd and even 4th time to commit to the study until they obtained the approval of the subject with the defense of their project and the final exam. The percentage of students who regularized the subject exceeded 70% in 2018, a very positive fact since the annual percentage of regularization in the last ten years has always been below 60%.

This fact often discouraged students since Biostatistics was not in their plans at the beginning of the career and therefore 30% of them stopped studying when they did not progress with this subject as it was very difficult for them. This analysis provides an indication that the project method substantially improves the assimilation of various statistical contents.

CONCLUSION

When applying the project method in the different commissions, we can observe significantly increasing percentages of approved students, and even the long-lasting problems with the *formulation and communication in statistical terminology* and *validation of the actions as well as the expression of conclusions in terms of the problem* have been substantially improved even though we could even achieve better results by systematizing, perhaps by providing support material and checklists (see also Borovcnik, 2018) to the students that may enhance the work on the projects and foster the efforts of the students, or by encouraging the students to cooperate across the groups, or by allowing them access to online help systems. It may also be a challenge for future work with the project method to support the students in the topic-finding phase and to get suitable data. Thus, with the application of the project method, satisfactory results in academic performance are observed. The theoretical basis and the highly satisfactory results of the experience with embedding the project approach into the courses in the Faculty of Veterinary Sciences (UNR) at our university constitute a methodological contribution that can reduce the incidence of factors that negatively affect (mismatch) the construction of meaning and the system of significant practices in the teaching and learning process of the topics of descriptive and inferential statistics.

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