HOW THE PROJECT METHOD CONTRIBUTES TO THE CONSTRUCTION OF MEANING IN STATISTICS – ALSO IN A HYBRID LEARNING ENVIRONMENT

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We address problems that arise in teaching statistics in non-statistical degree courses in statistics. The typical student reveals basic difficulties in the understanding of the key concepts. This paper describes experiences with the "project method", motivating students with real data from the future profession. The project method generated collaborative learning and social interaction between groups by embedding learning statistics in the context of applied problems in the form of projects. Godino's semiotic ontological framework provides elements of his model of the instructional process and a didactic trajectory in his first exploratory phase of execution, as well as exposing the linguistic, situational, actuative, conceptual, propositional, and argumentative elements that are relevant in understanding a particular topic. Due to its relative success in our classes and a theoretical analysis, we propose the project method for teaching statistics, especially for hybrid courses where face-to-face is combined with virtual parts of knowledge acquisition.

INTRODUCTION

We ground our considerations on the planning papers and on the experience with two different types of university courses, which both extensively used the project method for students' work. Based on our exploratory study, we propose to generalise the project method in inferential statistics, adapting it to the different university Master's Degree courses. One part of the study was carried out at the Centre for Interdisciplinary Studies of the University of Rosario during the pandemic in the course of the Thesis Workshop of the Political Master's Degree and Food Security Management in Argentina. The other part was ongoing seminars starting in applied statistics starting from the early 1990s in Austria. The link is the long-term collaboration between the present authors.

Statistics is an applied discipline. Major developments have been initiated by applied problems. About the essential role of applications in contrast to theory for studying statistics, we want to refer to the grand old R.A. Fisher whose driving force in developing new statistical methods always has been his problems from applications:

> "The tendency of modern scientific teaching is to neglect the great books, to lay far too much stress upon relatively unimportant modern work, and to present masses of detail of doubtful truth and questionable weight in such a way as to obscure principles." (Fisher, & Stock, 1915, p. 46).

Constituents of statistical concepts comprise

- theoretical mathematical considerations;
- the logic of the various procedures;
- and considerations on the matching of a model to a real situation.

In Fisher's intention, applied statistics is the only way to show what statistics really is about:

- Applied work is a perfect amendment to a careful education in the mathematics of statistics.
- To learn the mathematics only might bias the concepts.
- Textbook examples are useful to show the routine but fail to meet basic requirements of applied statistics, which is modelling!
- Artificial case studies might hide the complexity of applications.
- Authentic applied projects bear many risks, amongst others a primitive failure or tedious work but only using primitive methods; and they may be a risk for the client.

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Thus, statistics should be best taught within an applied framework. For the working mode, collaborative work corresponds to how people work in practice. We find good arguments for project work for learning in Álvarez (1990), Borovcnik (1995, 2018), or from a general framework of the didactics of mathematics in Godino (2003), or in the framework of action research, Krainer, Krainz-Dürr, Piber, Posch, & Rauch (1998).

THE PROJECT METHOD

According to Álvarez (1990), a project implies a desire or need, a prior agreement, an organisation and distribution of the work to be done and the roles. The project may arise from both the teacher and the student or from a need to articulate with the institutional curriculum; the important thing in any of the cases is to bear in mind that it always involves a prior elaboration by the teacher, who will determine its pedagogical intention.

A project is not based on themes from the discipline but on contents that emerge from the different actions to which it gives rise. Thus, it is not the theme that matters but the contents that emerge from that theme, both from a procedural, a conceptual, or an attitudinal perspective. The projects tend to generate autonomy and responsibility in the students. Its design consists of a scheme that explains why (objectives), what (contents), how (methodology), with what (resources), when (allocation of time), to develop the task by a learning group. Instead of introducing concepts and techniques that are decontextualised or applied only to typical problems that are hard to find in real life, the aim is to present the different stages of statistical research: problem formulation, decision on data collection, data analysis and conclusions on the problem, which is dealt with.

Anderson and Loynes (1987) point out that statistics is inseparable from its applications and its ultimate justification is its usefulness in solving problems external to statistics itself. On the other hand, we must differentiate between knowing and being able to apply knowledge. The ability to apply statistical knowledge is often much more difficult than assumed, because it requires not only technical skills (such as preparing a graph or averaging) but also strategic skills (knowing when to use a given concept or graph). Textbook problems and exercises tend to focus only on technical skills.

When working with projects, students are placed in the position of having to think about questions. Questions, which are asked in reference to statistics, taking into account the general characteristics as mentioned by the National Council of Teachers of Mathematics (NCTM, 2000) and by guidelines of modelling, when defining the objectives of the project work methodology (Graham, 1987; or Borovcnik 1995):

- What is my problem? What is the key question? How do I have to modify this question, that it is possible to get at least a partial answer to it?
- What do I have to measure, observe or ask? Do I need data to answer the key question? If so, which data contributes to an answer?
- How can I get this data? Is there comparable data available, or do I have to collect my own data?
- If I have to collect my own data, which is an appropriate method to get conclusive data on the key question: observation, planned experiments, or sampling from a suitable subpopulation, which may be regarded as representative.
- Which methods are adequate to analyse the data?
- How to interpret the results appropriately? Which graphs are suitable to make the results more accessible (also to the analyst)? Which assumption do the applied models use and how do these assumptions restrict the answer?
- What does this result mean in practice? What further problems arise and is the key question answered satisfactorily? Are further analyses including more data necessary?

DIDACTIC CONSIDERATIONS RELATED TO THE PROJECT METHOD

As Holmes (1997) suggests, if students work on statistics through projects, several positive points are achieved:

- The projects make it possible to contextualise statistics and make the concepts more relevant. If the data arises from a problem, it is meaningful data and needs to be interpreted.
- Projects increase interest, especially if the student chooses the subject. The student has a self-interest to solve the problem; it is not imposed by the teacher.

- Better learning of what the real data is and how important it is that it allows to answer the questions modified in the initial system-analytic phase.
- One learns more about what the real data is, and encounters problems that do not appear with data invented by the teacher: precision, variability, reliability, measurability, and bias.

The question-and-answer phase is one of the most difficult. Students seldom start with a clearly formulated problem. They could usually start without clearly defined questions, and the teacher's role is to help them move from a general topic to a question that can be answered. Nolan and Speed (1999) suggest that at the outset the teacher should not focus on statistical terminology, but provide general strategies that can be generalised to other data and contexts.

Work with projects raises the problem of the integral management of the elements involved in the class, so that students are oriented towards learning concepts of inferential statistics and improving their argumentation, conjecture formulation, and creativity skills. The objectives expressed by Anderson and Loynes (1987) were adopted:

- Work as a team and work within a set timeframe.
- Communicate clearly and effectively orally and in writing, through forums and chats.
- Determine the purpose of a research, and be able to contextualise it.
- Awareness of the need, in real situations, for an answer, even if it is imperfect.
- Efficiently organise data collection, recognise situations where data may be biased, know how to establish effective checks for the validity of data.
- Recognise the techniques appropriate to the problem. Analyse the data, interpret and use the results of the analysis.
- Read and critically interpret material, both statistical and related to the subject matter of the project (shaping argumentative thinking).
- Acknowledge the limitations of research. Recognise what statistics can and cannot do.

DIDACTIC TRAJECTORY OF THE PROJECTS

The didactic trajectory of each project, which was developed in the thesis workshop, is intended to answer the questions of the NCTM (2000) as follows:

1. *What is my problem? What is the key question? How do I have to modify this question, that it is possible to get at least a partial answer to it?*

The answer to this question requires a location of the research site and a description of the data relating to the context that will allow framing the problem precisely.

2. *What do I have to measure, observe or ask? Do I need data to answer the key question? If so, which contribute to an answer? How can I get this data? Is there comparable data available, or do I have to collect my own data?*

The answer to this question requires knowledge of the work process in the chosen establishment or location. Students may focus their activities by the following steps. *How to find the data? What to do with them? How can I get them? How to collect data?* Observation, surveys, or experiments? To make progress, students may analyse previously published similar works on the subject.

3. *What to do with the data?*

Through the information, the data will be organised into a database for inferential analysis as appropriate. What do these results mean in practice? What is its significance in relation to the problem raised? This is the key question that leads to an understanding of the subject under scrutiny and the need to interpret it in terms of the problem. The interpretation of these problem-related intervals challenges and trains the student in their capacity in argumentation.

EVALUATION OF THE DIDACTIC TRAJECTORY

For Sanjurjo & Vera (1998), project evaluation is a continuous and integral process rather than a single and final act, i.e., it starts from the beginning and is continuously linked to all other aspects of the learning process. Objectives, contents and activities are evaluated. Among the specific objectives, we try to integrate both those relating to the intellectual area (knowledge and intellectual processes) and those relating to the achievement of certain attitudes. The evaluation of activities is important because through them it is possible to better observe the steps taken to access the contents and to achieve the other objectives. If the learner is motivated to learn, assessment emerges as a necessity and not as an imposition. Another basic principle of a new evaluation system is thus inferred:

The analysis of the themes of the project was carried out with the groups and then the thematic units to include in the project were divided. For each thematic unit, four moments of analysis of the progress of the projects through forums were presented. In this way, errors were corrected together with the students of the group through discussion and argumentation of the procedures carried out by the students on the subject. Thus, they were able to overcome their difficulties and continually improve their proposals, even more by working in virtual classrooms. The demands of argumentation were emphasised, as this was one of the shortcomings known from previous experience in teaching practice. In addition, to strengthen this capacity, we held a monthly exchange, where each group commented on their work and made a personal reflection on their progress or setbacks in the project. These moments allowed the students to present their ideas, argue about their work, and prepare for the final evaluation of the project. The same students of the group evaluated the monthly pooling using the didactic strategy of metacognition and their opinion. The teachers evaluated the final pooling of each group using the scheme for evaluation in Table 1.

Table 1. Scheme used for evaluation process

Group Nº		Moments	Themes		
Members			•	•	•
Conceptual understanding (intensive elements)		1º			
		2º			
		3º			
		4º			
Procedural comprehension (actual elements)		1º			
		2º			
		3º			
		4º			
Contextualization of the problem (extensive elements)		1º			
		2º			
		3º			
		4º			
Formulation and communication in statistical terminology (ostensible elements)		1º			
		2º			
		3º			
		4º			
Statistical reasoning. Expression of conclusions (validation elements)		1º			
		2º			
		3º			
		4º			

CASE STUDIES AND PROJECT WORK IN APPLIED-STATISTICS SEMINARS

We report now about the series of seminars on applied statistics starting in the early 1990s and continuing to date. In consulting, the projects vary hugely in their demands, and the prior analysis of the task might lead to no end. Furthermore, the data production can be very lengthy and dominated by organisational work and the proper data analysis might be either routine work or too hard to perform. The organisation of all the steps of work may overburden the students and the clients might refuse students to work on their problems (for reasons of qualification, or for reasons of privacy, etc.). Therefore, we scanned our completed industrial projects and selected some projects that we judged to be suitable for use in a seminar. The advantages of a completed project are that a solution seems reasonable (as not all real problems can be solved satisfactorily). It is true that the cut-off of the data-generation phase took away some authenticity, but it saved a lot of time.

The basic idea was to simulate real practice as authentic as possible by "re-analysing" a project that has been completed at our department. At the beginning of the seminar, the work required in the several projects was described to the students carefully as it deviates from other seminars they are used to. The process of work has several steps, which are usually not part of the study:

Different roles. Students worked in teams of three to four jointly responsible for the success. The professor played the client who communicated on the problem.

Modelling phase (systems analysis). After some sessions with the client, the students delivered their systems analysis to the client who then challenged their first model. Students revised and finished their modelling work. As the systems-analysis approach is a crucial phase of application, the students had to generate their own perception of the problem and the relevant questions to pose. Their approach was challenged by a comparison to our approach in the past project. Pros and cons for either "work" were intensively discussed with all students.

Data collection (production). The students had to develop their own design of data collection: how to generate suitable data to answer the questions raised. As a drawback then, they had to match their systemic view of the problem with that of the finished project, as they had to use the available data. Yet, we informed them about our experiences and failures with the data collection to provide them a clear impression about the pitfalls of the data production.

Data analysis (the usual focus even in applied statistics). In exploring this data, the students had to check for their perception of the problem and for the assumptions of selected statistical procedures. Now the students were ready to search for statistical methods to answer the precise questions and hypotheses that were basic constituents of the initial systems analysis.

Contextual decision. Finally, the team wrote a report for the client and presented their results to the client and to the other groups. The data analysis was not isolated as usual. In their interpretation, the students had to refer to all the decisions and problems that have occurred throughout the process of modelling. As a characteristic of applied statistics, they concluded with partial solutions to the posed problem field and with open questions and topics for further investigation. This design of the seminar should make statistical investigations meaningful.

CHALLENGES AND BENEFITS OF CASE STUDIES AND PROJECT WORK

Challenges to the staff. We had to provide extensive support material for student work. A checklist that contained all relevant questions from initial modelling of a problem to the presentation of results (Borovcnik, 1993) supported modelling. Our manuals on the used software (SPSS) supported data analysis. Tutoring was provided to the students on demand on various methods in general and whether they were suitable for their questions.

Challenges to students. The extent of work was enormous; the variety of questions; the need to organise their work and acquire new tools, the qualifications to deal with the client, to develop a model from various input information, and to decide about suitable statistical methods was unprecedented for the students.

Benefits of the project method. The students learned on demand, they experienced the spectrum of projects also with the other groups; they corrected their intermediate understanding by discussing on their work in the group and by listening to the problems of the other groups. For an exemplary project, see Borovcnik (2018).

Once, the students have a rough overview on diverse methods for applied statistics, they may experience a boost in their comprehension when they apply them to real-world problems. Direct and short practical examples may serve for the illustration of the mechanics. It is very helpful to go beyond "clean" applied examples. The process of applying requires a mixture of general competencies including the skill to simplify the situation, to cope with the questions of an appropriate design, and to show leadership if the on-site situation differs from what has been planned. Applied project work requires also working in a team, and communicating statistics results across disciplines.

CONCLUSIONS

In the Argentinian project, the final approval rates for the project were considered as highly satisfactory. Those who did not show commitment throughout the development of the project or who were initially discouraged by the work of searching for information, left the Thesis Workshop. All the projects that continued were successfully substantiated. In the Austrian seminars, the students worked hard on their projects with amazing results. Several times, they questioned the original project reports with their own analyses. Many of them went on to specialise in statistics and are now working in statistics-related professions. We consider that the theoretical basis and the satisfactory results of the concrete experience constitute a methodological contribution that can reduce the incidence of factors that negatively affect (misalignments) the construction of meaning and the system of significant practices in the process of teaching and learning topics from inferential statistics. The higher workload of the students pays the effort as they learn much more behind the statistical concepts. To provide help systems, such as checklists, or tutoring on demand, also by a snowball system that engages student tutors, may soften the challenges and provide authentic learning for a wider circle of students.

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