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# Study and research paths in statistics: an ecological analysis

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*We present a study about statistics university education focusing on study and research paths. An SRP is a didactic proposal based on the inquiry of questions, introduced as a research and teaching tool within the Anthropological Theory of the Didactic. Our research addresses the problem of the SRPs' ecology in the first courses of statistics considering the conditions and constraints enabling or hindering the proposal to be implemented in a sustainable way. We perform a qualitative analysis of consecutive experimentations of the same type of SRP using the methodology of didactic engineering. In this paper we highlight the last stage of didactic engineering, the a posteriori analysis, and develop the analysis of the SRPs ecology at four levels: epistemological, didactic, pedagogical and school. In the results we emphasise the impact of the SRP in the course organisation and point out its strength of being both a research and teaching tool.*

*Keywords: Study and research path, anthropological theory of the didactic, project-based learning, statistics, ecology.*

## Introduction

Statistics has rapidly evolved during the past two decades, primarily thanks to technological developments that brought out the possibility and the need for collecting and effectively analysing massive amount of data. Such a change in the profession requires adaptations of the teaching of Statistics that keeps up with its application. A similar cause in architecture resulted in the beginning of a reform of its teaching back in Italy in the 16th century (Knoll, 2014). Knoll locates the origins of the Project Method as an instructional approach for “the academisation of a profession” and not the result of “abstract philosophical deliberations” (Ibid.). Throughout centuries, the method evolved, penetrating various branches at all educational levels and is continuing to adapt, grow and being disseminated. Nowadays, the most common expression for the method’s successor is “project-based learning” (PBL) (Batanero et al., 2013; Harmer, 2014).

The research works assuming the PBL pedagogical model in statistics teaching has grown steadily these past decades. These research works address two main aspects: first, its founding principles and second, the description of diverse teaching experiences (Markulin et al., 2021a). In addition, Batanero et al. (2013) propose implementing projects and investigations, bridging the relationship between the mathematical concepts and alive statistics environment, as a method to develop a “statistical sense” of the students. They show that the project fosters not only technical knowledge but a strategical one too (to know when to use a specific content or analysis tool).

As a contribution to the field of statistics education, our research follows the line of research within the Anthropological Theory of the Didactic (ATD) on the study of the ecological conditions in the design, implementation, analysis and development of a new type of instructional format – study and research paths (SRPs) – based on the continued inquiry of problematic questions (Chevallard, 2015).

In a way, SRPs include aspects of project-based learning (PBL). However, they also provide new perspectives and methodologies currently not elaborated in the PBL literature (Markulin et al., 2021a). The question addressed in an SRP has a main goal to generate an answer, regardless of the knowledge mobilised during the inquiry, while in PBL the central aim is meeting a specific piece of knowledge. This communication forms part of the first author's doctoral work on the advancement in the dissemination and impact of the SRPs in university education of statistics for non-mathematics students. We particularly analyse the didactic ecology of SRPs, that is, the conditions that allow their implementation in the classroom, and the constraints of all kinds (epistemological, pedagogical, school and social) that hinder their generalised development.

## **Research framework**

During the past 15 years, a line of research has been developed within the ATD to study the conditions needed for a change of the prevailing pedagogical paradigm. We are now in the paradigm of visiting works, where syllabi are usually a list of themes, topics or disciplines to learn, without necessarily knowing why it is important to learn them. The new paradigm considers knowledge as a tool to question the world and elaborate answers to the questions raised.

To analyse the conditions for transitioning to the new paradigm, the ATD proposes to design, implement, analyse and develop a new type of didactic device: SRPs. This proposal is based on organising teaching and learning processes taking the study of open questions as the central activity. These *generating questions* are posed to students in order to develop answers under the direction of a teacher or team of teachers. The process of elaborating the answers will give rise to research activities (such as: searching for information, collecting data, comparing the information collected, producing partial answers, etc.) and study activities to understand the information collected, acquire and be able to mobilise new tools of analysis. In that sense, the paradigm of visiting works is being replaced by a new paradigm: questioning the world. An important aspect to highlight is that in SRPs, the study of new knowledge or know-how is integrated into the research process (Bosch, 2018; Chevallard, 2015) and that they do not oppose transmission and inquiry.

The research follows the line of implementations of SRPs in chemistry, business administration (BA), medical sciences and mechanical engineering and continues in the case of statistics in BA degrees. These investigations show different modalities of SRP's integration in the courses and their management using different tools originated in didactic research, such as question and answer maps, research and study dialectics and the methodology of didactic engineering (Barquero et al., 2020).

## **Research questions**

The emphasis of this communication, and the doctoral work it forms part of, is to address the problems associated with teaching statistics at the university level in a moment where knowledge in this field is evolving rapidly. We investigate actions that can and do appear in the process of the change from the traditional teaching of statistics towards the acknowledgment of the evolution of the profession and its application in the teaching of it. Our research questions are:

- What conditions can be established in a current degree of business administration (in Spain) to organise a first course of Statistics in the transition between paradigms (where the students' work is led by the need to answer some questions instead of the need to visit some works)?
- What constraints appear at the epistemological, didactic, pedagogical and school level?

To answer these questions, we rely on the literature about similar teaching proposals, their design and implementation, as well as on our own research experiences.

## Methodology

As said before, this work is framed in a wider research project intending to study the ecology of SRPs at higher education institutions. More specifically, our research group has been implementing SRPs in experimental sciences (Barquero et al., 2011), engineering (Florensa et al., 2018; Bartolomé et al., 2018), and business administration (Markulin et al., 2021b) among others. The first approach to study the conditions and constraints governing the implementation of SRPs at higher level takes a macro-didactic point of view and assumes as an object of study the collaborative work needed between researchers and lecturers to design and implement SRPs at higher education. Previous research showed that the ecological fragility of the implementation of SRPs is due to the fact that in most experiences the researcher and the teacher are the same person (Florensa et al., 2019). Our work intends to explore how this collaborative work, materialised in teams of researchers and teachers, can address this issue and to what extent this collaborative setting may enhance the long-term viability of SRPs at higher education. Our proposal is not far from the practitioner-researcher collaboration as described by action research method that faces similar challenges concerning this situation where the researcher and the teacher are close collaborators or even the same person (Townsend, 2014).

The second approach is the study of the ecology of SRPs by designing, implementing and analysing SRPs at higher education level, in particular in the fields of mathematics and engineering (STEM). We follow Florensa's (2018) proposal on the use of Didactic Engineering (DE) to do so. In fact, one of the main particularities of SRPs compared to other PBL proposals (Markulin et al., 2021a) is the existence of this four-phase methodology (Barquero & Bosch, 2015). The first phase is the *preliminary analysis* where the institutional conception of knowledge is explicitly characterised in order to identify the foundations of the didactic phenomena addressed. The second phase is the *a priori* analysis of the SRP that will include not only the selection of the generating question but also a new proposal of the knowledge at stake considering it as a consequence of the inquiry process. The third phase is the *in vivo* analysis concerning the implementation and observation of the SRP as well as the data collection. Finally, the fourth phase is the *a posteriori* analysis. The main work is to analyse collected data, to compare the *a priori* analysis with the actual activity experienced, to describe the different roles played by teachers and students and to highlight the constraints and conditions identified during the implementation.

In this work we adopt this second approach, and we analyse the implementation of three SRPs in a second-year course on statistics in Business Administration degree at IQS School of Management (Barcelona, Spain). We present here the last phase of the DE methodology, this is the analysis of empirical material generated during the implementations (further details on the design and the implementation of the SRPs can be found in Markulin et al., 2021b; Bosch et al., in press). The first implementation was done during the year 2019-20, the second during the year 2020-21 and the third implementation is ongoing (fall semester of year 2021-22). We have collected and analysed different students' productions (weekly reports, final reports), we have also conducted naturalistic teachers' observations, and students have filled in surveys. The survey had been previously piloted in other SRPs implementation (Florensa et al., 2018) and can be found here (<https://sites.google.com/view/cerme12-statistics-srp-ecology>). To complete this information, we

have conducted semi-structured interviews with students focusing on students' experience regarding: the aim of the study, data gathering, teamwork, assessment, etc.

## **Results and discussion**

In this section we present and discuss the results obtained during the last phase of DE methodology. We propose an overview of the a posteriori analysis structured in four levels of didactic co-determinacy: epistemological, didactic, pedagogical and school (Chevallard, 2015). For each level we present the conditions and constraints detected during the implementations of the SRPs. An overview of the results is also shown in Table 1.

### **Epistemological level**

The different implementations of the SRPs have caused important modifications at the epistemological level. Changes at this level are very challenging as they tend to modify the curriculum, or at least to heavily modify the previous conception of knowledge. This modification contrasts with the prevailing epistemology at the institution: that is the conception on what statistics is and the attributed *raison-d'être*. Even if the adoption of the European Higher Education Area standards led to competence-based curricula, the institutional conception, often implicit and ill-defined, remains in terms of conceptual organisations and pieces of labelled knowledge.

For the case of statistics, we consider it as an area where its epistemological modification towards a knowledge conception in line with the paradigm of questioning the world is favourable. First, because scholarly knowledge is evolving rapidly, especially in the past 20 years with significant technological developments and a shift in the way of collecting and dealing with data. Secondly, because statistics is placing the focus of the course more on the interpretation of the results than on the mathematical procedures that are at the foundation of the calculations, and this fact enables a better fit with the degree of BA and nurtures the motivation for the field. Nowadays, there is no shortage of questions and problems to pose when proposing any activity or project in the teaching of statistics.

However, this favourable situation is not without a challenge: a transposition work needs to be done to reorganise the praxeological components of the statistics organisations. This didactic transposition process should consider the selection and adjustment of the scholarly knowledge to become the knowledge to be taught. In the process, new technologies in the ATD sense will get elaborated to adapt into better correspondence with the statistics software as well. Epistemologically, the area is compliant with the creation of new exercises and teaching proposals. Nevertheless, teachers can have a lack of legitimacy to "invent" new teaching materials and knowledge organisations. In our case, such a constraint is not an issue thanks to the freedom that the teacher-researcher has for transforming the knowledge to be taught according to some didactic and epistemological principles.

Interviews with the students revealed their views on the project and the area of statistics in general: "I think I learned more in the project than in the rest of the course", "I learned that you could know something about subjective things about people and that, if you could do it with vegetable diets, you could also do it with other subjects, such as politics."

### **Didactic level**

On the didactic level, we consider a crucial point that the community of study takes the SRP's generating question seriously. The need to produce an answer is, in fact, the generating force of the

whole inquiry process and points to the direction for the final answer to be presented. However, the variables governing this process are difficult to identify and of diverse natures.

The first variable identified is the origin of the dataset, this is if the dataset and the survey are given (external) or produced by the community of study (internal). In the first two SRP implementations, the survey was composed by the marketing experts and the students were in charge of collecting the data. We considered that this external origin would engage students because of its closeness to a real setting. However, in the interviews we found out that the external origin of the survey led to students' detachment mainly because of the difficulties to understand its structure and questions: "At the beginning the questions seemed strange. But when we started analysing with graphs and summaries, we started understanding it." Consequently, for the third implementation, we plan to build the project survey together with the students, making it more a product of internal descent to encourage the involvement, making the structure more understandable than in the previous implementations.

On the other hand, the receiver and validator of the question and its answer can be inside the course, the institution or from outside the education setting. We administer a combination of internal and external receiver/validator, depending on the step of the project. Derived questions and the feedback provided based on the intermediate students' reports are validated by the course teachers, while the final answers are presented for the external jury (members of the institution and the external client). The validation of the results is announced beforehand using an evaluation rubric which forms part of the established didactic contract. Furthermore, the case studies during the course, before the project, help introduce (or train) didactic strategies and devices that are later vastly used in the project activity. An example of such a strategy is a practice of always starting with a  $Q_0$  that is open and needs to be studied in several sessions, meaning it is presented as an activity that requires deep attention and investigation by the students and cannot be solved within 20 minutes or even in one session. The teacher is then a guide in the process and not an instruction giver.

### **Pedagogical level**

As the business requirements for our students require collaborative work, most of the students' activities during the statistics course we present are carried out as teamwork. On top of that, the idea of an SRP by the ATD proposes raising above the individual work. It encourages connecting, interfering, brainstorming and advancing in a problem setting by interaction within and between groups. Case studies that form the course before the project, apart from being managed in teams, cherish investigative environment and set pace to the statistical activity. They have a fixed duration of two weeks and always end with a submission of a team report that is afterwards corrected by the teachers. The culmination of the project, on the other hand, occurs in a session of posters or presentations, depending on the conditions the course is going under (pre-pandemic project finished with poster sessions in the classroom, during the pandemic project finished in online presentations). Although the project is being organised and driven by the problems that are considered relevant for the students' degree, statistics remains a topic from a group of courses based on quantitative methods. On average, this brings a pre-established aversion of the students towards the course and a lack of dedication in its components. However, the inclusion of a project is perceived as a valuable stimulation for some of the low-motivated students, as noted in the interviews: "It makes a huge difference; what we will encounter tomorrow, the fact that our work is going to have an impact on the work of different people".

**Table 1: An overview of the SRPs conditions and constraint and their evolution**

	CONDITIONS	CONSTRAINTS	EVOLUTION
Epistemology	<ul style="list-style-type: none"> <li>◦ Flourishing area of research</li> <li>◦ Area of knowledge in fast evolution</li> <li>◦ Importance in BA</li> <li>◦ Facility to modify the knowledge to be taught</li> </ul>	<ul style="list-style-type: none"> <li>◦ Prevailing epistemology: difficulty to accept new organisation of knowledge</li> <li>◦ Didactic transposition work needed to adapt new areas of knowledge</li> </ul>	From SRP1 to SRP2: <ul style="list-style-type: none"> <li>◦ Re-scheduled detaching from traditional organisation (kept during SRP1)</li> </ul> → Planning SRP3: continue the praxis from SRP2
Didactics	<ul style="list-style-type: none"> <li>◦ External Q<sub>0</sub> proposed by real companies - partners</li> <li>◦ Report writing</li> <li>◦ Final assessment</li> </ul>	<ul style="list-style-type: none"> <li>◦ Data are given</li> <li>◦ Difficulty to incorporate new tools by students</li> <li>◦ Didactic contract based on external validation of answers</li> </ul>	From SRP1 to SRP2: <ul style="list-style-type: none"> <li>◦ Incorporation of intermediate reports allowing to give feedback to students</li> <li>◦ The project was initiated earlier in the course</li> </ul> → Planning SRP3: continue the praxis from SRP2
Pedagogy	<ul style="list-style-type: none"> <li>◦ Teamwork</li> <li>◦ Calendar of the course: case studies</li> <li>◦ Oral presentation</li> </ul>	<ul style="list-style-type: none"> <li>◦ Low degree of students' engagement</li> <li>◦ Lack of creativity</li> </ul>	From SRP1 to SRP2: <ul style="list-style-type: none"> <li>◦ COVID pandemic heavily affected the development of SRP2</li> <li>◦ Explicit management of the process of study in the second edition.</li> </ul>
School	<ul style="list-style-type: none"> <li>◦ Assessment</li> <li>◦ Computer availability</li> <li>◦ Use of free software R</li> <li>◦ Moodle, MS Teams</li> <li>◦ Teacher's accessibility</li> <li>◦ Small groups</li> </ul>	<ul style="list-style-type: none"> <li>◦ Private university: complaints on changing the terms of didactic contract</li> </ul>	The school stays the same

### School level

At school level, we present our institutional setting, a private university, shows no or few changes from one SRP implementation to another. A direct consequence of the COVID19 pandemics was the implementation of the MS Teams for all the teachers and students. There were also vast investments in the technological equipment to ensure the quality and synchronous teaching and interaction, but no other changes. Teachers have the autonomy to arrange assessment of the course (two to three teachers depending on the implementation, well connected and easy to agree between themselves) and to adapt it from one year to another. They also have freedom with the calendar organisation of the course (no need to be in accordance with teachers of other courses or with the instructional organisation). The students' attendance is compulsory, and they are organised in relatively small groups (big teacher-student ratio compared to usual university groups). Each student owns a personal computer and is required to always carry it. In Statistics we introduce R software, more precisely its user interface R Commander, and use it in every session. For the provision of the materials, we use a learning platform Moodle. Implementing the SRP in a private university modified its initial schedule due to the students' requirements for extending the pre-SRP sessions devoted to statistical inference. Conditions are certainly different in this respect in Spanish public universities.

## Conclusion

The consecutive implementations of SRPs in statistics for BA students allow us to transform the Statistics course in several aspects. The didactic phenomenon at stake becomes questioned before and after every implementation, providing new perspectives both from the epistemological (the profession) and the didactic (reorganisation and enrichment of didactic devices) point of view. In a way, already by seizing to detect the phenomena in the foundation of the professional area, occurs the questioning of the educational setting and puts the basis for the design of the SRP. Furthermore, according to the teachers' observations, every implementation that was experienced suffered from different or repeated obstacles. Such constraints bring to consciousness the impact of different didactic strategies or influences originating in other levels, whether epistemological, pedagogical or the school. For example, in the statistics course presented, the case studies facilitated certain skills that appear in the SRP as well. However, this situation can be a limitation, for instance, when a certain activity appears in the project but is not previously encountered during the case studies. The analyses of each implementation support the common findings and stimulate the design of the following implementations of the SRP and the course in its entirety. The long-term viability of the SRP implementations to this Statistics course is still under study. In addition, a major ecological change will take place in 2022-23 when the researchers will not be involved in the course anymore.

In the line of the SRPs developments, we cannot avoid stating that an SRP is a transformative and questioning instrument, not only for the students but also for the teachers who design the course. We observe that the implementations of SRPs progressively influence the organisation of the program. If it was first included as a complement to a course typically structured according to the logic of the contents, it gradually gained more prominence and made the content subordinated to the anticipated needs of the research. This goes in favour of extending the unit of analysis of the SRPs' methodology to the entire course of Statistics.

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