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## The evolution of a study and research path in Statistics

Kristina Markulin, Marianna Bosch, Ignasi Florensa & Cristina Montañola

**Abstract.** We present the organisation of a first course in Statistics for Business Administration degree students, which includes a study and research path (SRP) as an inquiry-based teaching proposal. The paper aims to summarise the course's evolution, design, and reflections on both its different components separately as well as altogether as a complete unit. The analysis considers different perspectives to the course, the student's, the teacher's and the researcher's, thus providing a critical perspective. It also includes the joint evolution of the course and the SRP. Under the Anthropological Theory of the Didactic framework, we show that the design and management of the SRP cannot be detached from the course as a whole. We see how the course components nourish the SRP and how this, in return, makes the course content evolve and adapt to the student's professional needs. The inquiry proposal needs a multidimensional approach, both in its planning and dissemination of its outcomes in the research and professional literature. Therefore, our study can contribute to didactics research about SRPs, serve as a starting point for the newcomers to inquiry-based teaching and as a reflection point to foster collaborations between researchers in didactics and lecturers.

**Keywords.** Anthropological theory of the didactic, Statistics, University Teaching, Study and Research Paths, Project-Based Learning, Inquiry-Based Learning.

**Résumé.** Nous présentons l'organisation d'un premier cours de statistique destiné aux étudiants en gestion d'entreprise, qui comprend un parcours d'étude et de recherche (PER) en tant que proposition d'enseignement basé sur l'enquête. L'article vise à résumer l'évolution du cours, sa conception et les réflexions sur ses différentes composantes, séparément et dans leur ensemble, comme une unité complète. L'analyse prend en compte les différents points de vue sur le cours, celui de l'étudiant, celui de l'enseignant et celui du chercheur, offrant ainsi une perspective critique. Elle inclut également l'évolution conjointe du cours et du PER. Dans le cadre de la théorie anthropologique de la didactique, nous montrons que la conception et la gestion du PER ne peuvent être détachées du cours dans lequel il s'inscrit. Nous montrons comment les composantes du cours nourrissent le PER et comment celle-ci, en retour, fait évoluer le contenu du cours en l'adaptant aux besoins professionnels de l'étudiant. La proposition d'enquête nécessite une approche multidimensionnelle, tant dans sa planification que dans la diffusion de ses résultats dans la recherche et la littérature professionnelle. Par conséquent, notre étude peut contribuer à la recherche en didactique sur les PER, servir de point de départ pour les nouveaux venus à l'enseignement basé sur l'enquête et de point de réflexion pour favoriser les modes de collaboration entre chercheurs en didactique et enseignants universitaires.

**Mots-clés.** Théorie anthropologique du didactique, statistiques, enseignement universitaire, parcours d'étude et de recherche, enseignement par enquête, enseignement par projets.

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### 1.A. Introduction: project-based learning in Statistics

Statistics has rapidly evolved during the past decades with the so-called data revolution characterised by the incorporation of technology allowing to manage and analyse huge amounts of data. These significant developments pushed some authors even to propose changing the name of the discipline into “data science” (Cleveland, 2001). The teaching of statistics at the university level is not immune to these changes, even if it evolves at very different rates. The materialisation of this evolution generally includes the incorporation of software and the work with real datasets that are easily accessible and treatable with the software. It is furthered by recommendations like the one of the American Statistical Association with its Guidelines for Assessment and Instruction in Statistics Education (GAISE) College Reports (Carver et al., 2016). The report proposes to “teach statistics as an investigative process of problem-solving and decision-making” (op. cit., p. 13). It suggests that “a way of incorporating the investigative process into a first statistics course is to ask students to complete projects that involve study design, data collection, data analysis, and interpretation” (op. cit., p. 14). These conditions favour the introduction of new instructional proposals, many claiming to adopt the principles of problem-based (PBL) or project-based learning (PjBL).

Even though PBL and PjBL proposals are flourishing, published research mainly focuses on their effects on the students’ achievements. In a detailed review of the literature on PjBL in statistics (Markulin et al., 2021a), we observed a lack of attention to the conditions under which the proposals are implemented and the way teachers manage them, together with the difficulties found and the strategies deployed to deal with them. Furthermore, the changes these proposals require and also produce on the teachers’ conception of the knowledge at stake usually remain implicit. Finally, little information is given about the integration of the new proposal into the course and their joint evolution, that is, the way the PBL activity modifies the original structure of the course. These limitations can be related to a lack of tools to describe the teachers and students’ activities during the educational process and the insider position adopted by researchers that puts teachers’ concerns in the spotlight.

This paper aims to present a first university course on Statistics that integrates a project-based proposal as a core activity. We will show the design, implementation, and analysis of this proposal by considering the course’s main organisation and the relationship between its different activities and the project. Because the course has been implemented during three consecutive academic years, we will show the evolution of the project as well as the entire course during the different editions. Our description assumes that the considered unit of analysis embraces both the project and the course that integrates it. This delimitation is essential for the type of didactic phenomena that can be approached. Finally, this course is an example of collaboration between researchers in didactics who teach the course with another lecturer who is not a researcher in didactics. The conditions for such collaboration will also be considered.

### 1.B. Theoretical framework

Our research is based on the Anthropological Theory of the Didactic (ATD) and its approach of inquiry in terms of *study and research paths* (Chevallard, 2015). The ATD proposes to consider two main didactic paradigms, one that prevails in today educational institutions and characterises teaching and learning processes as “visiting works”; another that is just emerging and embraces the previous, where teaching and learning processes take place in a broader activity of “questioning the world”. Curricula in terms of lists of topics or notions, and the role of teachers as those who know and organise students’ learning are essential aspects of the paradigm of visiting works. The introduction of competencies as curricula definers and the recent flourishing of inquiry-, problem- and project-based instructional proposals can be interpreted as symptoms of the crisis of the old paradigm and movements to make it evolve towards the paradigm of questioning the world.

A major difference between the two paradigms is the role played by the knowledge at stake: in the first paradigm, knowledge works are “visited” because of their intrinsic importance. In contrast, in the paradigm of questioning the world, knowledge is studied because of its capacity to answer questions or to generate new ones. In the approach of questions through inquiry processes, the visit of works also enriches the set of tools needed to explore the questions and elaborate answers. In this case, however, the visit is always directed towards the aim of answering the questions addressed: works will then be studied for their utility to the inquiry, and only for this.

A didactic phenomenon identified by researchers regarding mathematical courses to non-specialists in higher education is the so-called *applicationism*. According to it, elementary knowledge is first acquired and later *applied* to solve questions in different contexts (Barquero et al., 2013). We can consider that *applicationism* conceives both paradigms as consecutive - first the visit, then the questioning -, while maintaining the prevalence of the first on the second. For example, Barquero et al. (2014) show that heat transfer laws are often presented as applications of differential equations. This phenomenon reduces the modelling activity that can exist in an institution: modelling becomes reduced to an exemplification process. We consider that the same phenomenon occurs with statistics in higher education, leading to the implementation of inquiries, the main goal of which is to exemplify the use of previously introduced statistical tools.

The implementation of inquiry study processes at higher education is hindered by a specific set of conditions and restrictions: the *ecology*. One crucial element of this ecology is the way mathematics, including statistics, is conceived in higher education institutions. This epistemological conception heavily affects the study processes that can (or cannot exist) in a specific institution.

The specific instructional proposal of the ATD to foster the paradigm shift when implementing inquiry processes are the so-called study and research paths (SRPs): an inquiry-based teaching format with an associated design and analysis methodology. An SRP is initiated by a generating question ( $Q_0$ ) addressed to a community of study formed by a group of students ( $X$ ) and a guide or guides of the study ( $Y$ ). The question will generate a combination of investigation activities (search for new and relevant information) that will help in the research process till the elaboration of an answer to  $Q_0$ . The implementation of an SRP is often twofold: on the one hand, SRPs promote a paradigm shift (Bosch et al., 2018; Chevallard, 2015), modifying the didactic activity in a specific school institution. On the other hand, SRPs can also be considered a research tool to identify, modify, and study didactic phenomena, that is, regular facts in teaching and learning processes and specific to the content involved. Diverse SRPs have been implemented at the university level in mathematics, statistics and engineering courses, with different modalities of integration (Barquero et al., 2020).

A particularity of SRPs is the existence of a specific four-phase methodology for their design, implementation, and analysis: the so-called *didactic engineering* (Barquero and Bosch, 2015) (see Figure 1). The first phase is the preliminary analysis that describes and characterises the didactic phenomena to approach with the SRP and its relationship with the way knowledge to be taught is conceived in the teaching institution. *Applicationism* is an example of such a didactic phenomenon that hinders the teaching and learning of mathematics as a modelling tool. Another example of a phenomenon related to statistics is the invisibility of data handling, which relegates the processing of data (searching, collecting, organising, cleaning, etc.) to a secondary position when it does not simply ignore it. The second phase of didactic engineering is the a priori analysis that corresponds to the design of the SRP. It includes the selection of the initial question  $Q_0$  of the inquiry process, considering its capacity to generate new questions and checking that the study community ( $X$ ,  $Y$ ) will be able to obtain enough resources to elaborate an answer to  $Q_0$ . Also, some general aspects of the inquiry organisation and specific didactic devices can be considered, such as logbooks to keep a

trace of the inquiry for each student team and the whole group, the submission of intermediate reports, etc.

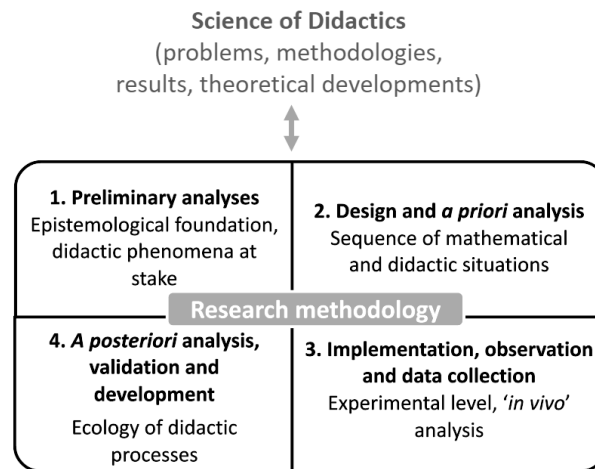


Figure 1 – The process of didactic engineering (adapted from Barquero & Bosch, 2015, p. 263)

These two first phases also address the following aspects. First, it is necessary to describe a possible evolution of the new questions that can be derived from  $Q_0$ , the knowledge works that will probably be accessed, and the corresponding data or information obtained. This description indicates a possible pace for the inquiry and corresponds to its *chronogenesis*. Second, it is important to explicitly model how the knowledge and material resources available during the SRP will evolve: the so-called *mesogenesis*. The mesogenesis, or evolution of the inquiry *milieu*, includes the incorporation of new information and partial answers and their contrast or validation to turn them into new ready-to-use knowledge tools to proceed with the inquiry. Finally, the way how responsibilities will be shared between teachers and students is considered through the *topogenesis* or evolution of the *didactic contract*.

The third phase is the *in vivo analysis*. It includes the management of the inquiry and the way decisions are made during the process, by teachers and students in the classroom and also by the team of teachers-researchers between the sessions. The main information source here is the observation of how the inquiry is progressing and the intermediate results obtained that regularly modify the initial provisional planning. Finally, the fourth phase is the *a posteriori* analysis, where data collected during the implementation is contrasted with the preliminary and *a priori* analyses in terms of mesogenesis, chronogenesis and topogenesis. This last phase includes a study of the didactic ecology of the SRP about the conditions that facilitate its running as well as the constraints that hinder it.

## 1.C. Description of the Statistics study and research path

### 1.C.a. Institutional conditions and general course organisation

We are here considering three editions of a course of Statistics that takes place in the second year of a bachelor's degree in Business Administration in IQS School of Management in Barcelona (Spain). For students, it is the first course with statistics content after graduating from high school. During the first year of the degree, students have courses in mathematics and informatics. Through these courses, students are transitioning from the high school mathematics content to the knowledge to be applied in business administration. In the mathematics course, the software Excel is partially used, while in Informatics, it is the main computing tool. One of the aims of implementing software usage in the courses is the nourishment of computational skills of the students that are preparing to

enter the labour market as competitive experts in their field. The statistics course aims to provide students with a set of useful tools, including statistical software (Excel and R), to collect, analyse, and interpret data to understand, control, model, and forecast quantitative information involving variability.

In the three editions of the course, groups are formed of roughly 30-50 students, two of the groups attending the course in Spanish and the third one in English. Statistics is organised as a one-semester course (15 weeks) with two 2-hour weekly sessions (60 hours in total) and 6 ECTS credit weight. The course was coordinated by two teachers, one in charge of the two Spanish groups, the other for the English group. During the second and third editions, a third teacher was assisting in all three groups classes. Table 1 presents the educational and research backgrounds of the courses' teachers. Having two teachers in every session is a favourable condition for such a course organisation because it results in a lower demand per teacher, both in the class interventions with the student groups and the continuous assessment of the students.

The course syllabus consists of describing datasets with descriptive statistics and graphs, relationships between variables, models of distributions, inference, and hypothesis testing. All statistical analyses are performed with R Commander, a basic graphical user interface for the statistical program R. The course is a mixture of theory and genuine practice.

The course is organised in bi-weekly case studies, 5 or 6 in total, depending on the course edition. Each case is based on a different dataset being analysed using different statistical tools. These tools are progressively introduced according to the analysis needs. In the first two editions of the course, the first case study is an introduction to descriptive statistics using data from a students' survey. Already from the beginning, it poses the issue of the data cleansing process students carry out mainly using Excel. Later on, case studies are based on datasets given by the teachers and usually do not require data cleaning. The second case study more systematically focuses on the description of relationships between variables. The third and fourth cases include the description of discrete and continuous probability distributions (uniform, binomial, normal) and start addressing sampling situations. The last cases approach the analyses of data obtained from a survey, using hypothesis tests to check the significance of some observed values or differences between variables to complement graphical and numerical summaries.

Students perform the cases organised in teams of 4-5 members. They can change the team between different cases, but the experience shows that these changes rarely occur. During the cases, the teachers present the dataset to analyse and the questions to address. Then they progressively introduce statistical techniques and theoretical developments students need for the case. At the end of each case, students are required to submit a team report with their answers to the case as part of the subject assignments. In parallel or after the bi-weekly cases, depending on the course edition, the project of the course takes place. The project implies a complete statistical analysis, from data collection to the presentation of the findings, to address a given question, different in every course edition, which corresponds to a real and current study proposed by an external instance. The teamwork organisation in the cases applies to the project too.

The evaluation of the course subject is done grouped into two parts: individually through written exams and collectively through team cases and the project. The weight of each part's grade varies in different course editions, depending on the cases and the project organisation. The decision on the grade partition is taken among the Statistics teachers and is therefore flexible and subject to yearly revision. In the last edition, individual and team assessments had the same weight, 50% of the final grade. Individual assessment in the last edition was organised through two midterm exams (20% of the final grade each), one in the middle of the semester, the other just before the last weeks completely devoted to the project. The final exam (30% of the final grade) takes place at the end of

the semester, two weeks after the project is completed. The team grade includes the evaluation of the case reports and the project intermediate and final reports. A detailed description of the last edition's project is presented in the next section.

The course is primarily constituted around the project work, having it as a means for the study process as well as an immediate application of the knowledge and skills acquired by working on short and partial case studies. The cases and the project are meant to be carried out both during and outside the sessions. In class, students' work benefits from the constant availability of two teachers guiding, proposing, and helping the teams on-demanding the process. A crucial material condition that allows such development of the students' work related to the constant software usage is the bachelor's degree "one student-one personal computer" requirement. Each student owns a personal computer and is required to carry it to every class.

The organisation of the course slightly differed in the three last editions that this paper is concentrated on (Table 1). In the first and second editions, the course was divided into two sequential parts. The first part included the classes structured in bi-weekly cases and culminated with a midterm exam. After the exam, the project sessions started and continued to the end of the course, lasting for three weeks. However, the project topic was introduced a few weeks before the midterm exam and students were asked to collect data using the survey provided. The survey, which is the source of the project data, was prepared by marketing experts from the school, but collecting the answers was the students' part of the work. Eventually, by the time they had taken the midterm exam and the project sessions started, the data was collected and ready for the cleansing and analysis process. Other than the students' final presentation, there were also voluntary intermediate submissions during the process for those interested in obtaining complete feedback on their progress. Later, it turned out to be of utmost importance in focusing their results for the ones who used the opportunity of such feedback. A complete in vivo and a posteriori analysis of the above mentioned second edition of the Statistics course is presented in Markulin et al. (2021b).

The third and most recent edition of the Statistics course has a slightly different organisation because the two parts (cases and project work) run mostly in parallel. However, the real change occurred when normal presence classes had to switch into mostly online classes for the epidemiological reasons of the COVID-19 pandemic. Unlike the project weight of 30% of the final grade in the first and second editions (with cases grading for 20%), the project assumed the entire 50% in this third and last edition. The reason for the change was twofold. First, it emphasised the importance of the project and the expected study time devoted to it. Second, the nature of the project (hardly to be copied) made it a more valuable assessment tool since the sessions were online.

<b>Academic year</b>	<b>2018/19</b>	<b>2019/20</b>	<b>2020/21</b>
<b>Project</b>	$Q_0$ and survey related to residents' tourism perception	$Q_0$ and survey from research about vegans' motivation, values, and consumer behaviour	$Q_0$ and survey about a cooperative supermarket (clients' profile and location)
<b>Course organisation</b>	<ul style="list-style-type: none"> <li>- Cases 1, 2, 3</li> <li>- Project presentation</li> <li>- Cases 4, 5 in parallel with project survey data collection</li> <li>- Midterm exam</li> <li>- Project (last three weeks)</li> </ul>		<ul style="list-style-type: none"> <li>- Project presentation</li> <li>- Cases 1, 2</li> <li>- Midterm exam 1</li> <li>- Project</li> </ul>

			secondary data collection
			- Cases 3, 4, 5 in parallel with project survey data collection
			- Midterm exam 2
			- Project (last 3 weeks)
<b>Assessment</b>	30% project 30% final exam 20% midterm exam 20% case reports		50% project 30% final exam 20% midterm exams
<b>Teachers (and their professional background)</b>	A teacher - experienced researcher in didactics (second author of this paper) and a teacher-researcher in computer science (fourth author)	A teacher - experienced researcher in didactics (second author) and a teacher assistant - beginner in didactics research (first author)	The three previous teachers

Table 1 –Summary of the three editions of the Statistics course

### 1.C.b. Implementation of a study and research path

The SRP's generating question comes either from a real demand or from a research proposal outside the subject. In the first and the second projects, the question arose from research projects conducted at the marketing department of the same school. The third question was proposed by a real company (see next paragraph for further details). The collaboration between the statistics and marketing departments is ensured by the well-developed interdepartmental relations and regular meetings of the teachers. For the third SRP, the connection with a real sector was possible thanks to the corporate-university relationships.

The most recent course edition involved a new project performed slightly differently from the previous editions. The project topic was introduced to the students by an actual client, a company that proposed an exploration of the Barcelona residents' consumer behaviour and their intention to participate in the set-up of a cooperative supermarket. Therefore, the project's topic started being tackled during the second week of the course, with the question of describing the potential target clients and finding the best location in the city for the supermarket. After the company's presentation, students left the project aside and continued working on bi-weekly case studies that were not directly related to the project, but served to build a theoretical and practical base. In the meantime, experts from the university marketing departments worked on assembling a survey to obtain data for the project.

After completing three case studies, the project was returned to. The teachers propose exploring Barcelona's official statistics data and getting a better idea of the different districts in terms of population, number of shops, rental prices, etc. This first step was to help organise the survey's implementation and to check the quality of the sample afterwards. This study was



elaborated using Excel, the software that students were quite familiar with. The findings, submitted by each team in the form of an intermediate report, served as a basis for detecting possible bias when disseminating the survey for the project. The activity turned out to be quite challenging, especially because it coincided with a switch to a completely online modality of the classes.

Later, the partial exam took place and the bi-weekly cases continued with different topics. In that period, the survey was already composed, presented to the students by the authors and supported by the marketing research frameworks and the hypotheses that were behind the survey's components. Students started disseminating the survey that was the same for all the groups. Since the epidemiological circumstances at that point impeded normal mobility, the students were left to choose a tactic for data collection. Since the project was teamwork, the teachers suggested the collection of at least 100 answers by each team. Even though the survey was anonymous and did not collect the data of the survey provider, the progress of data collection was traceable since each team had their own weblink for the survey. That way, both the students and the teachers could keep track of the collection progress.

When approaching the end of the classes, three weeks (6-7 sessions) were left for the project work. Initially, it was planned for the project to take the last four weeks, but the pre-exam period was prolonged because the online modality made the student-teacher in-class interaction slower and more difficult to manage. During the last project period, students were asked to submit two more intermediate reports, one on the analysis of the sample (the survey dataset) and the other one on the preliminary results of the analysis of the consumer behaviour of the respondents. All three intermediate reports (one about the official city statistics and the two just mentioned) obtained detailed feedback from the teachers for students to continue their work. Since there was no content from the competency-based syllabus left to be studied, the students discussed their actions regarding the project with the teachers via private team video calls during the classes. Those discussions mostly occurred at the students' demand and were rarely forced by the teachers. Even though there were two available teachers in each session to address students' questions, not all the project work could have been finished only during the official session time slots. With the online modality of the course, the students got used to the online work rhythm, and that also facilitated a more flexible and approachable way for the student team members to meet and continue the work "out of the class".

The final presentations took place during the last session of the course. After submitting and receiving the feedback of three intermediate reports, students were left to summarise their teams' analyses and prepare a ten-minute presentation. The exposition of the presentations was attended by the whole student group and a three-member jury. The jury was formed of one of the statistics teachers and two teachers from different school departments (marketing, accounting, ethics, quantitative methods) that were not familiar with the project topic. After each team's presentation, a discussion session followed where the team members had to answer the jury's questions while the jury was filling in an assessment rubric proposed by the Statistics teachers. The final presentation grade (40% of the project grade) was given as a summary of the jury's assessment.

#### **1.D. A priori and a posteriori analysis**

The analysis of the described SRP implementation is planned as a set of quantitative and qualitative analyses of different perspectives towards the project. We distinguish three positions to be considered when reflecting on this specific SRP: a student, a teacher-researcher in didactics, and a teacher-not researcher in didactics. The students' perspective is analysed quantitatively, using their responses to an after-project survey, and qualitatively, conducting semi-structured interviews with a smaller sample of 2 students per group. A similar, although not equally extensive, data collection and analysis was performed for the second edition SRP (Markulin et al., 2021b). The new conditions for the last SRP opened more roles and tools to consider, such as the quantitative analysis of the students' survey (Florensa et al., 2018) and the experience of the teacher who is not a

researcher in didactics (the teacher in charge for the two Spanish groups). The collected data is in the process of analysis at the time of writing this paper. Therefore we present a brief insight into the reflection on the experimented SRP.

Two teacher-researchers in didactics were the initiators of the project implementation, its design and the analysis. The third teacher adopted the plans and collaborated on their adjustments during the implementation. The experience was discussed a posteriori among the teachers, and the feedback, from the teacher-not researcher in didactics, is positive. She considered that the experience was positive, and she is motivated to continue with the course organisation. However, a tiresome component is the amount of time invested in the course organisation and the corrections of all the cases and project reports, on top of the well-established exam grading.

Teachers-researchers in didactics based the a posteriori analysis on some hypotheses that sustained the design of the SRP related to its different components (generating question, elements of the milieu and evolution, final answer) and the didactic devices implemented to ensure the SRP development. Among these didactic devices, we find: presentation of the problematic situation by an external instance, formulation of the generating questions, organisation of students in teams, survey proposal and data gathering, preparation of intermediate reports to rhythm and guide the inquiry, sharing of results in the whole group, oral presentation of the final answers. However, the design of the SRP cannot be separated from the design of the course and its related activities. We will present at the same time this a priori analysis that guided the course and SRP design and the a posteriori analysis performed once the course is finished. We will structure this section by distinguishing the epistemological foundation of the instructional proposal, its *chronogenesis*, *mesogenesis* and *topogenesis*.

#### **1.D.a. Epistemological foundation**

The Statistics course's main content and instructional goal correspond to a broader conception of the statistical activity as "dealing with datasets". This conception has traditionally not been considered part of formal statistical knowledge that at higher education has been conceived as more formal and based on a deductive structure of theorems and proofs. By contrast, this new conception makes new tasks to be explicitly considered such as data collecting, sample design, data cleansing, data organisation, a systematic combination of descriptive and inference tools, report writing and presenting. As part of this goal, the SRP implemented in the course represents the culmination of the proposal as a way to make some essential uses of statistics in business and management visible.

For this purpose, and in what concerns statistical knowledge and the associated competencies, the SRP cannot be considered independently of the other instructional devices of the course organisation. In particular, an analysis of the a priori analysis of the different courses show an evolution in the course design and the cases that structure it during the three consecutive editions. Specifically, in the first edition, the cases were built according to the classical epistemological conception of statistics at higher education: one-variable descriptive statistics (case 1), relationships between two variables (case 2), theoretical distributions (case 3), sampling and inference (case 4), hypothesis tests (case 5). However, in the last edition, the structure of the cases was rethought to better correspond to the different aspects that arose from the previous SRP implementations. In this sense, case 1 was oriented to a preliminary graphical and numerical description of a "clean" dataset, including relationships between variables, case 2 was deepening into the analysis by considering a dataset gathered by the students from an ad-hoc survey, and case 5 included a stronger relationship between hypothesis tests and descriptive analysis. This change in the case organisation shows how the inclusion of the SRP affected the evolution and organisation of the whole course contents (even outside the SRP).

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Contrary to expectations, the non-didactician lecturer in charge of the course felt comfortable with the organisation of the third edition of the course and did not ask for a more theoretically-oriented proposal or the inclusion of specific statistical tools. We interpret her flexibility as partially due to her lack of experience with the university institution she had just integrated (Statistics was one of the first teaching subjects). It is also certainly related to her confidence in the senior teacher-didactician co-responsible of the course and also, of course, her open-minded perspective about statistics and university teaching. It is important to mention that her background was primarily in computer science (engineering degree) and secondarily in statistics (PhD), which can explain a certain detachment from the traditional scholarly organisation of the subject.

### **1.D.b. The dynamic of the inquiry: chronogenesis**

The evolution of the last SRP implementation brought about an improvement in some aspects of organisation and performance. Introducing the generating question during the first week, presenting the survey to gather data at the end of the first month, and proposing an activity about Barcelona city's official districts data in the middle of the course, helped to keep the generating question of the SRP central during the entire course. Teachers could refer to it in the previous cases, and students could better manage the data gathering. Thus, in comparison with the previous SRPs, this last implementation had a better temporality.

In their research about SRPs, Florensa et al. (2018), following Winsløw et al. (2013), suggest the use of "questions-answers maps" as a tool to manage the evolution of the SRP because they help point at the derived questions and provisional answers the student community generates during the inquiry. During the a priori analysis and according to these research results, teachers agreed to ask for question-answer maps to be included in the intermediate and final reports of the students. Even if an explicit training about the use of the maps was planned in the first session, it was not implemented. The lack of this training was not considered critical because the students already used the maps in the reports submitted for the previous case studies. However, despite this previous work, and without any specific teaching session, students did not spontaneously use questions to describe the knowledge structure during the SRP. They only incorporated them in the intermediate and final reports under the teachers' demand, without using them as a communication tool between peers. To this respect, the previous work with questions in the cases was not enough to make the question-answer dialectic explicit during the inquiry without the teachers' intervention.

Another aspect that arose during the SRP implementation was the lack of joint work of the group class. After the presentation of the project by two persons of the cooperative supermarket to the whole group of students, they started to work in teams of 4-5 members that did not share a clear common goal. Even if the generating question was unique, the students were free to choose blocks of concerns (e.g., specific intention to engage in the presented supermarket, the consumerist and environmental values the respondents cherish, etc.) they wanted to focus on. This option was proposed to facilitate the sharing of tasks among the teams. However, the in vivo and a posteriori analysis showed that the SRP ran as different parallel SRPs, each team leading its own. There was no time to organise sessions to present, share and discuss the results so that each team could take advantage of the others' progress. Students' choices resulted in final reports proposing more or less partial solutions depending on each team's preferences. So, the collaboration between teams with similar focuses, or different ones to complete the full picture, did not occur – at least according to the teachers' knowledge. This enterprise seems difficult unless there exists a motivation for all the class-groups to engage in the creation of a joint answer. One can think, for instance, in an external assessment by the client of the whole group report made by the different teams, with a repercussion in the individual grading of the students.

### **1.D.c. The dynamic of the inquiry: mesogenesis**

The mesogenesis analysis demonstrate that it becomes important to enlarge the unit of analysis from the SRP to the entire course. If we only consider the SRP and its generating questions about the profile of the cooperative supermarket customer/member and the best location for it, the main elements that student teams incorporated in their milieu were the data gathered from the survey, some secondary data about the city's districts to compare with the sample obtained, and the partial results they were obtaining while doing the statistical description of the data. They did not have time to search for new statistical tools – for instance, new sophisticated graphs, cluster analysis or an analysis of reliability – and only exploited the resources that were already available at the moment. Also, to the difference of the previous editions of the course, and because of the online teaching, teachers did not organise any specific session for student teams to share their results and validate or complement their findings with those of the other teams.

However, in what concerns the validation of results, we can observe two elements that did not appear in the previous editions. The first one is the use of secondary data to analyse the quality of the sample obtained: knowing the percentage of people living in each Barcelona city district and their distribution in terms of age, gender and income help study the limitations of the samples obtained and, consequently, of the generalisations that could be drawn. Even if the proposal to search for secondary data was made – and closely guided – by the teachers, it did reach the student teams milieus and were of benefit for the inquiry. The second one is the internal statistical validation of the results obtained. Thanks to work done in the last cases, students could connect the use of hypothesis tests to the need for validation hypotheses found by previous descriptive analysis based on graphs and numerical summaries. However, even if this comment can seem trivial, it is not evident for students to know how to use and interpret a hypothesis test and determine in what occasions it is worth using. In other words, it seems that during the project work, students used hypothesis tests because they needed to validate some findings, not just because it was part of the subject content.

### **1.D.d. The sharing of responsibilities: topogenesis**

The way responsibilities are shared in the process and how each member assumes different roles is called the topogenesis of the inquiry: the generation of different places or topos to teachers and students. The interviews with students carried out after the end of the course showed, as expected, that addressing a question posed by the members of a real cooperative project improved students' engagement. Moreover, the cooperative supermarket project was located in Barcelona, the same city where our university is. Being in geographical proximity to the students, allowed them to engage in an ongoing project affecting their neighbourhoods' everyday life. Students also valued the interaction with the clients - the representatives of the cooperative supermarket - at the beginning of the project, even if this interaction was not as fluid as we wished due to the online teaching conditions.

During the post-project interviews, the students mentioned that teachers guided the project work without being too directive: "And the feedback from the teachers was more or less quick. Sometimes we expected more, but it was not a crucial thing." However, from the teachers-researchers perspective, it seemed that students did not generate many more inquiries beyond what the teachers proposed during the process. Such perception is based on experience, such as the following one taken from another student's interview transcript: "Maybe just for some of the deliveries, especially at the start when we didn't know what we really had to do. The professor sometimes gave us intermediate feedback stating that we were on the right track, but then graded lower than what we anticipated. She would then propose what more could have been done, but we had not thought about it. We would have done it if we had known so." Again, the unexpected online

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teaching did not facilitate the teachers' guidance and, particularly, the large group work to share results, validate them and discuss possible ways to go on.

The type of responsibilities assumed by the students did not differ from the one established, at the beginning of the course, but was perceived by the students as developing and more demanding towards the end of the course. It is possible that students were (or felt) less guided during the project because they already knew what to do and how. The role of the cases to develop students' responsibilities was especially noticed during the first intermediate report of the project – the analysis of Barcelona official city districts secondary data – which corresponds to a type of activity that was not previously addressed during the cases and generated confusion in students' decision making.

### **1.E. Conclusions**

The implementation of a study and research path during three consecutive editions of a Statistics course for Business Administration sheds light on different aspects of the design and analysis of this type of inquiry-based proposal, as we now summarise.

The first result concerns the delimitation of the unit of analysis, that is, the extent of the empirical reality we should consider when conceiving, describing, and evaluating a given teaching proposal. The case presented shows a clear inseparability between the SRP and the course it is part of. In the design process, it is obvious that the implementation of an SRP should consider the organisation of the entire course, even if it is run only during the last weeks and after the final exams. The way the SRP affects the course is seen after each implementation, in the modifications teachers decide to introduce because the SRP reveals the importance of some elements that would remain invisible otherwise. In the same way, from the didactics perspective, it makes no sense to analyse an SRP without taking the global didactic project into account. For example, integrating the course case studies with the SRP affects the epistemological foundation of the teaching project. It corresponds to a conception of statistics that locates the inseparability between data collection and data analysis at the core of the statistics course. As shown by Markulin et al. (2021a), many investigations report project-based proposals isolated from the analysis of the global teaching process that incorporate them. We can read it as a clear symptom of the “applicationism” tradition where the learning – or visit – of the content goes first, and mostly independently, of its use during the project realisation.

The second conclusion is a direct consequence of the previous one. It concerns how the implementation of an SRP has affected the evolution of the course during the three editions. When the project appears as a materialisation of the course's main objectives, it is normal for teachers (and researchers) to discover new elements during each implementation, thus enriching their conception of what “Statistics for Business Administration” is or could be. In the case here considered, we observed an evolution where the course components (cases, midterm exams, etc.) progressively incorporate project elements that did not appear in the first description of the course content. This joint evolution between the SRP and the course content is a phenomenon already identified by Barquero (2009) and Florensa (2018). For instance, in the first case, Barquero shows that in the four editions of an SRP run in parallel with a traditional mathematics course (with lectures and problem sessions) introduced a lot of modifications in the lectures and problem sessions that tend to converge to the SRP's dynamics. If the first SRP could appear as a complement to the course, in the last editions the leadership relied on the SRP, and the lectures and problem sessions were more and more structured to cover the SRP's mathematical needs.

When considering together the implementation of the SRP and its relationship with the other course activities, especially the cases, we can better understand what facilitates the students' autonomy during the inquiry process. Some of the resources needed to pursue the inquiry, like the

techniques for data cleaning and report writing, but also some complex conceptual strategies related to hypothesis testing, all these resources were available thanks to the work done in the cases. This work also contributed to progressively transferring new responsibilities to the students, like teamwork, work planning, validating results and raising new questions for further research. However, this previous work also produced limitations. In the last edition of the SRP, maybe due to lack of time caused by online teaching and the pandemics, students struggled with gathering secondary source data, an aspect of the SRP that was not included in the cases activities.

We can interpret this limitation in a double way. On the one side, it appears as part of the normal development of the course design and shows the need to incorporate dealing with secondary source data into its core content. On the other side, it is also a consequence of the traditional didactic contract in statistics that tends to provide students with ready-to-use data and let them focus on other supposedly important things. And it is reinforced by the traditional pedagogical contract of the paradigm of visiting works that limits the students' search for new information outside the class. Nevertheless, it also shows that the dependencies between the SRP and the course need to be considered in a double way, because each SRP will have its specific demands and the previous course activities cannot foresee all their possible needs – at the risk of falling back into applicationism.

Finally, in what concerns the possible ways of collaboration between researchers in didactics and lecturers who are specialists in other research areas, we can find here a productive experience, similar to the one described by (Florensa et al., 2018). Lecturers and didacticians collaborate as teachers of the same course and, therefore, share the implementation of innovative instructional formats led by the didactician. Assuming the co-responsibility of a course between didacticians and lecturers facilitates the cooperation work because it does not need any specific extra organisation: implementing an SRP is part of the joint course preparation and does not appear as something special. Even if the first design of the course mostly relied on the lecturer-didactician, the other lecturer also participated in the decisions made and assumed the proposal as her own. Then, in the next editions of the course, the division of responsibilities was progressively shared on the lecturer's side. Moreover, this kind of cooperation also ensures sustainability by progressively making the experience less researcher dependent. It appears as an effective compromise solution in a university setting that does not have any "teaching support" position that could help better define the role of didacticians in relation to lecturers who are not specialists in didactics. In any case, other forms of cooperation need to be established to let university teaching take advantage of the knowledge and methodological resources provided by research in didactics. More research is needed to elaborate a sustainable collaborative methodology between didacticians and lecturers for the design and implementation of instructional proposals. However, this work will be useless if we do not study, at the same time, the institutional conditions need to sustain such a collaboration.

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Kristina Markulin  
Universitat Ramon Llull, IQS School of Management  
e-mail: kristina.markulin@iqs.url.edu

Marianna Bosch  
University of Barcelona  
e-mail: mariannabosch@ub.edu

Ignasi Florensa  
UAB, Escola Universitària Salesiana de Sarrià  
e-mail: iflorensa@euss.es

Cristina Montaña  
Universitat Ramon Llull, IQS School of Management  
*e-mail:* cristina.montanola@iqs.url.edu