TEACHING STATISTICS WITH PROJECTS AT THE UNIVERSITY: A CASE STUDY

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We present the implementation and analysis of a study and research path (SRP) in Statistics for business administration students. An SRP is an instructional proposal developed within the Anthropological Theory of the Didactic based on the inquiry of open questions. Our analysis focuses on the in-process evolution of the SRP, as well as the qualitative a posteriori analysis of its implementation. The results help describe interesting instructional devices for their design and management and identify some critical challenges that explain the difficulties of their dissemination in university education. We emphasize the need for educational research to focus on the conditions and constraints that enable and hinder the existence of project-based learning activities in current educational systems.

INTRODUCTION

Statistics is a branch of applied mathematics that is undergoing a significant evolution in the last 30 years. During the 1990s, it has started to be defined as data science and the emphasis began to be put on the importance of the empirical data and the context they come from. Wild and Pfannkuch (1999) point out the need for data, their visualisation and the reasoning within the statistical context. Such a shift in the professional area of statistics, followed by substantial technological developments enabling the collection, treatment and analysis of a big amount of data, posed a challenge to the education system as well. The teaching of statistics tends to or at least should tend to follow the recent changes in scholarly knowledge. However, the initiatives and reforms of education take time and do not follow the developments in the professional areas instantly.

As one way of adapting the teaching of an area to its professional evolution, Knoll (2014) detects the emergence of the Project Method as an instructional approach for the training of architects in the 16th century in Italy. During the centuries, teaching methods with similar ideas grew and were reshaped, for today to still be adapted and used in education at all levels and around the world. Nowadays, the most common expression for the successor of the Project Method is *project-based learning* (PjBL) (Harmer, 2014). In statistics, Batanero et al. (2013) suggest implementing such an instructional approach to connect the mathematical concepts and the statistics environment, therefore developing a "statistical sense" of the students.

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Related to the PjBL movement, we are here considering a proposal coming from the Anthropological Theory of the Didactic (ATD) based on the continued inquiry of problematic questions, named *study and research path* (SRP) (Chevallard, 2015). We can consider SRPs as a broad instructional format that encompasses PjBL and provides a methodological framework for its design and analysis. In the case of statistics, literature on the PjBL commonly focuses on the students' learning and perceptions towards statistics before and after the project implementation, while the SRP approach puts a strong emphasis as well on the questioning of the statistical activities that are taught, the planning of the learning process and especially the in-process observations and analyses (Markulin et al., 2021a). In this paper, we will illustrate this through an implementation of an SRP in statistics for business administration at the university.

THEORETICAL FRAMEWORK

Throughout the past 15 years, the ATD yielded a line of research to study the conditions needed for a change from the prevailing pedagogical *paradigm of visiting works* towards the one of *questioning the world*. In the former paradigm, the syllabi are usually a list of themes, topics or disciplines to learn, without necessarily knowing their raison d'être. The latter 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 instructional proposal, the SRP. This proposal considers open questions as the central activity of the teaching and learning processes. An initial question generates an arborescence of derived questions to be answered by the students under the direction of a teacher or a team of teachers. In the pursuit of elaborating the answers to the questions, different *research* activities will appear (searching for information, collecting data, comparing the information collected, producing partial answers, etc.), as well as *study* activities to understand, acquire and put into practice the new knowledge and analysis tools (Chevallard, 2015).

Until now, several applications of different SRPs have been implemented in university education for students in engineering, chemistry, medical sciences, economics and business administration (Bosch, 2018; Lucas, 2015; Markulin et al., 2021b, Parra & Otero, 2017; among others). Those implementations vary in duration and moment in the course when they take part in. They share however some crucial aspects that, taken together, specify them among other PjBL proposals. First, the fact that students work in teams and that teams collaborate to address the same problematic question: the SRP's *generating question*. Second, the use of particular instructional strategies and tools, such as maps of questions and answers, the elaboration of intermediate reports, the search for new information and data and their corresponding study, and the presentation or defence of the final answer (Barquero et al., 2021). Finally, the use of a specific methodology – the *didactic engineering* (see below) – that provides a general framework to design the SRP in relation to the global structure of the course.

We will describe the implementation of such an SRP and its analysis through the teachers' observations and the students' answers to a questionnaire and semi-structured interviews. Our focus will be on the integration of the SRP in the global Statistics course organisation and the interaction between both.

THE SRP IMPLEMENTATION

In the academic year 2020/21, we implemented an SRP in a 6 ECTS Statistics course for second-year business administration students. It was the third year to implement an SRP to that particular course by two researchers in mathematics education who had the teaching responsibility. The Statistics course has a duration of one semester and is organised in two parts that are intertwined: the traditional part combining lectures with case studies, and the SRP-project part that mainly occurs during the last three weeks.

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 first part of the course is a mixture of theory and genuine practice. It is organised in bi-weekly terms centred in case studies to yield some descriptive statistics of the data given, introduce models of distribution, inference analysis and hypothesis testing. Each case is based on a different dataset being analysed using different statistical tools. These tools are progressively introduced according to the analysis needs.

The 2020/21 implementation of the SRP started by posing an initial question coming from an association that proposed an exploration of the city residents' consumer behaviour and their intention to participate in the set-up of a cooperative supermarket. The project was proposed at the beginning of the semester and was retaken in the middle of it for an intermediate report on the city's different districts using official statistics. 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 activity turned out to be quite challenging, especially because it coincided with a switch to a completely online modality of the classes due to the COVID19 situation.

Later, the partial exam took place and the bi-weekly cases continued with different topics. During this period, students could collect the answers to a survey elaborated specifically to answer the association's demands. When approaching the end of the classes and data were collected, three weeks (6-7 sessions) were left only for the project work. In this 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. During the online classes, interactions and discussions with the teachers mostly occurred on the students' demand and were rarely forced by the teachers. Even though

there were two available teachers 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".

Students were required to present their answers to the association during the last session of the course. The exposition of the presentations was attended by the whole student group and a three-member jury formed by 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. A more thorough description of the 2020/21 implementation can be found in Markulin et al. (in press).

RESEARCH QUESTIONS AND METHODOLOGY

Our research focuses on the role of SRPs as instructional facilitators of the shift between the pedagogical paradigm of visiting works towards the one of questioning the world. This contribution's specific research questions are:

> RQ1: What elements of the course organisation facilitated the implementation of the SRP? Which ones hindered it? What other constraints appeared?
>
> RQ2: How can the identified constraints be related to the *paradigm of visiting works* prevailing in university education and what consequences can be drawn towards the general dissemination of PjBL proposals?

To develop some answers to the posed research questions, we considered the implemented SRP as a case study and rely on qualitative research as part of the *didactic engineering* (DE) methodology (Barquero & Bosch, 2015). For the *a posteriori analysis*, the DE last phase, the source of our data are the naturalistic observations of the statistics teachers (who are also researchers in mathematics education), as well as semi-structured interviews to a small sample of students, and a questionnaire passed to the students after the course. The interviews were done with 5 students from different groups and having different Statistics final grades, while the questionnaire was anonymously answered by a sample of 71 students up to 113. The interviews and the survey addressed all the parts of the SRP and its relation to the course organisation: interest of the generating question; data collection process; clarity of the project aim; survey composition; availability of statistical tools; classes organisation (online and synchronous); students' teamwork; final presentation of results; calendar and duration of the project; relationship with the case studies; etc. Our hypotheses were:

H1. *Generating question and project aim*. The fact that the association representatives formulated the generating question and students had to present the final results in front of a jury brought realism to the project. However, the initial question did not seem to be considered real enough by the students during the analyses.

H2. *Project survey and data collection*. Social networks provided students with facilities to collect data, despite their reduced mobility due to the COVID19 situation.

However, exploiting the data to get interesting answers to the questions raised required more time and students' investment.

H3. *Integration of the SRP in the Statistics course*. The classes previous to the project provided tools and knowledge for the project work. They also prepared students to use inquiry strategies and resources, like data collecting and cleaning, raising questions, summarising results, etc. that are part of the "statistical sense" (Batanero et al., 2013).

H4. *SRP organisation and management*. Even if the SRP took place during the last three weeks, some learning resources, like teamwork and report writing, were introduced in the previous case study sessions. The schedule of the project (at the beginning, middle and end of the course) gave visibility to the SRP all along the course, even if the global time devoted to the data analysis seemed too short.

RESULTS AND DISCUSSION

In the following paragraphs, we present the interviews and questionnaire results associated with the different hypotheses (students from the interviews are denoted as S1, S2, S3, S4 and S5).

H1. The students confirmed our impression that the project's initial question was clearly posed. However, unlike the teachers' observation of the students' detachment from the core issue, they considered themselves well immersed in the matter. S2: "The question is well-posed and is exploited because the whole project was based on that question…later we started to understand, we saw examples, the advantages from there to continue, we started to integrate and understood what the association was pursuing"; S3: "I was not considering it [the initial question] during the project but in the end, our final presentation, it was then when we focused everything on what the association needed". Regarding the teachers doubt whether they guided the students' analyses too much, and unintentionally making an open problem too academic, the questionnaire students answered resulted with a mean of 2.5 on a scale from 1 to 5 as an answer to the question: "The teachers guided us too much: (1 being not at all, 5 being too much)". About the final presentations, they were mostly proud moments for the students where they could present and defend their results in front of their colleagues as well as the evaluating jury. S1: "In our case, we did not have to elaborate much the presentation. It was a subject that we already had so well established and so integrated that in the end, it came out on its own."; S4: "I liked it. I think the presentation could have been a little longer, maybe there was a lot of information and it had to be reduced. But overall, it was good." Moreover, according to the questionnaire, the students seemed to appreciate the assessment by a jury. As an answer to the question "I think it is important that there are external evaluators for the final presentation (1 being totally disagree, 5 being totally agree)" the mean of the answers was 3,8 and the median a 4.

H2. About the data collection, the process went indeed without major issues, probably thanks to the fact that the respondents could have been of all age and social groups (unlike some previous projects that demanded specific respondents' characteristics)

S1: "It is true about the COVID19 issues, but nowadays, with the social networks and the level of expansion, I think we reached the same people as we would have without the COVID19 issues". Moreover, some students suggested simplifying the survey to improve the project results. S5: "A simpler and easier to answer survey would have gotten the most reliable results for sure". However, the questionnaire gave us a mean of 2.8 and a median of 3 on a scale from 1 to 5, a quite symmetric distribution, as an answer to the question "The data collection was easier than I expected: (1 being totally disagree, 5 being totally agree)" which is satisfying since it shows that data collection is a part of statistical work that is not trivial but can be simplified if the survey is well composed and the target respondents are not a very reduced group of people. In what concerns the lack of students' engagement with the survey's richness, S4 mentioned the responsibility they felt for the project, but also that it was not shared by all the teams: "If all our colleagues from the group really thought they had a responsibility, it could have made a difference in the form of how the project was to be developed. At least it was what I expected."

H3. The combination of theory, case studies and a project in a Statistics course has shown as engaging but at the same time providing a steady base for the application of learnt skills as well as acquiring some new ones along the way of analysis of the real-world data. S1: "It was nice to learn a bit about the tools like R that are widely used in companies and at universities, as well as the theory. Everything has its application"; S3: "Maybe I learnt some things that I ended up not using for the project, but as more as we learnt the more we could apply, and it helped us explain more things eventually"; S5: "I think that I learned to do it while doing the reports because it was a progressive thing with the cases. For the project later, we had the basics to start with".

H4. The students appreciated the teamwork. S1: "In the end, no matter how much you want to, you will have to work in a team at some point or another. This is why it is very important that you adapt to different ways of doing things"; S3: "I think that last year, in the first year of the degree, I did not have the same ability to communicate in a group as I have now"; S4: "I think it has to be done as a group, first of all, because in statistics many topics are touched upon. There are many questions and some of us is going to be better in certain problems while the other team members will be more skilled with another type of analysis." In what concerns the intermediate reports, even if they had a tight schedule, the students confirmed that they helped them focus their analyses. S1: "Handling the deliveries...we were there for a month, almost every week...we were on top of everything. And the feedback from the teachers was more or less fast. Sometimes we expected more, but it was not a must, either."; S3: "In the end, we had a hard time grasping what you wanted to get from us. Then, in the end, the last reports, we saw much more what you wanted and it was easier for us." Finally, the calendar of the project was mainly well organised and did not disrupt the flow of the theory classes and the case studies but was reminding the students that the big project is to be kept alive in their consciousness and they could think about the project ideas while learning the theory. S5: "I think it was good that at the end it was more squished in time because

you were working on it quite regularly and you did not lose the hang of things, you knew what was going on. Maybe the only thing I would say is there was a void between the project presentation by the company and the first report, so I remember some people saying: Oh, what was this association like? What is happening with that?"

All in all, the general impression the students stated, which was satisfying for the teachers as well, is that they appreciated the connection of a university course to a real company and found it useful for their future professional and personal experiences. S1: "I think it is a way that helped us to do a little bit of market research, which in the short term will be something we will have to do when we are working."

CONCLUSIONS

Concerning RQ1 (facilitators and constraints in the implementation of the SRP), if we only focus on the SRP, the presented experimentation did not add substantial elements to the existing investigations. We corroborate the students' difficulties in raising questions and taking them "seriously" (Hypothesis 2), as well as searching for validation tools outside the teachers' approval or feedback. We also confirm the need to base SRPs on the study of real generating questions to ensure that it is the question that leads the inquiry and not the knowledge tools needed to elaborate an answer (Barquero et al., 2021). However, if we consider the SRP together with the course implementation, the experimentation reinforces the interaction between both teaching strategies. The students' ease in searching and cleaning data, preparing summaries, working in teams, elaborating written reports and defending their results in oral presentations can be explained by the inclusion of these activities repeatedly since the very beginning of the course. They cannot be learned in a three-week activity.

About RQ2 (constraints related to the paradigm of visiting works and consequences for PjBL proposals), the main lesson we can draw affects the unit of analysis that is considered by research on project-based teaching. Our experience illustrates how the structuring of the course cannot be considered – from a design nor a research perspective – as separated from the project. An SRP is not a longer activity the teacher includes at the end of the course, as an "application" of some previously visited works of knowledge. On the contrary, it is part of a course globally designed to provide students with practical competencies in dealing with data and, therefore, culminates with the study of a real managerial question requiring its approach through data collection and analysis. We consider that research on PjBL would gain in delimiting broad units of analysis that include the courses where the projects are implemented, instead of detaching them from the PjBL strategy. Probably, many of the constraints hindering the dissemination of PjBL instructional proposals do not come from the proposals themselves but from the global teaching activity that integrates them.

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