How does noise affect our health? Analysing a project-based activity in Statistics at secondary level

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Teaching statistics through projects brings to life in the classroom aspects of working with data that are not usually part of traditional paper-and-pencil activities. There exists a generalized agreement about the positive effects of this kind of teaching proposals and number of international and local initiatives to foster them at secondary and tertiary level. Despite all this, their sustainability as normalized classroom activities is very fragile, given in particular the extra amount of work required to teachers willing to implement them. Research in didactics can help better understand the conditions that enable the introduction and management of statistics projects in the classroom, as well as the – sometimes invisible – constraints that hinder their development. We illustrate it with a case study based on the implementation of a statistics project in a classroom of Grade 9 students, using recent developments of the anthropological theory of the didactic.

Keywords: Statistics education, project-based teaching, noise pollution, study and research paths, anthropological theory of the didactic.

Introduction: Statistics project competitions in Catalonia and Spain

Despite the influence of recent didactics research in the Spanish intended curricula at secondary level, one can still find in textbooks "some inertias, inherited from previous curricula and from traditional uses of statistics, with many algorithmic procedures, leaving few spaces for critical thinking, decision making, and analysing solutions within a context. Additionally, the official intended curriculum still has some outdated standards regarding the use of tables, and an excessive emphasis on mathematization of statistical procedures" (Rodríguez-Muñiz et al., 2018, p. 419). Furthermore, the topics of statistics tend to remain the last to be taught at the end of the academic year, and thus the first to suffer reduction due to rescheduling necessities (Angulo et al., 2013).

Since 2006 in Spain and 2009 in Catalonia, university departments of statistics supported by scientific societies launch annual competitions for projects based on surveys and experiments carried out by secondary school students. In the case of Catalonia, about 70 projects are presented every year, with 200 students, 30 teachers and 15 schools (1.5% of the total). The contest includes three categories. These competitions appear as good opportunities to involve teachers and schools in the implementation of inquiry- or project-based teaching proposals, creating an external motivation for students and increasing the visibility of their work. What teachers and students do and how they organise their inquiries is certainly very diverse. According to Markulin et al. (2021), project-based learning in statistics is a broad term that refer to different teaching proposals, ranging from open individual inquiries to strongly guided collective activities.

The teaching proposal we are analysing emerged in this context of statistics competitions. It was implemented by the first author, a mathematics teacher with 16 years of experience. It has evolved during the past five years as the teacher, together with the students and schools, have gained more experience. We focus on the last project implemented in the academic year 2020/2021 with Grade 9 students, which won both the Catalan and the Spanish awards in their category. After describing the experience, we will introduce some analytical models from the anthropological theory of the didactic, especially the notion of "study and research paths" (Chevallard, 2015) to present a critical analysis of the didactic process. The results obtained will help us draw some hypotheses about the difficulties found for the implementation of such proposals and possible ways to overcome them.

A Statistics project in Grade 9 about noise pollution

Five years developing projects to teach statistics

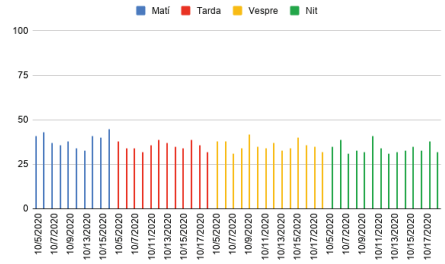
The project we are considering was implemented in a secondary school in Rubí, an industrial town in the outskirts of Barcelona with around 90.000 inhabitants. The idea of teaching statistics through projects in secondary education first appeared six years ago when the teacher had to deal with a group of unmotivated students with low skills in mathematics. To raise interest in the class she designed a survey with a topic of interest for the students, they gathered the information and then perform a simple descriptive statistical study: tables of frequency, graphics and centralization and deviation measures. The following years, the implementation of the projects went on, and the way of teaching statistics was improved through them. One fact that fostered this improvement was the contest "Incubator/Seedbed of surveys and experiments". In addition, the attendance to the awards ceremony, where winner projects are presented, also helped widen the teacher's perspectives. This led to last year's project "The noise and how it affects our health", which was run during 24 weekly sessions of 50 minutes with two groups of 30 students and consisted of two phases or parts.

First part: How noisy is our town?

The first phase of the project took place in the first 12 sessions. It consisted of an investigation to know how noisy Rubí is. We can distinguish different steps in the project development. For the first two sessions, the teacher searched previous studies and information about the topic and prepared a presentation about what the noise is, an official noise map of the city published in the Town Hall website, a Google Maps for each student to locate a pin in their home address. Once the class saw that students' neighbourhoods could "cover" a vast enough space, the teacher proposed a survey with questions about the characteristics of the streets that can affect the noise level. She also presented DecibelX, a sound level meter app. Students answered the survey and carried out a descriptive statistical analysis. With all the information, students made their own hypotheses.

The data gathering was done in two steps. With the help of the mobile application DecibelX, students measured the amount of noise outside their houses. Measurements were carried out for two weeks, starting on the 5th of October 2020 and finishing on the 18th of October 2020, and on certain times: from 7am to 8am (morning), from 5pm to 9pm (afternoon), from 9pm to 11pm (evening) and from 11pm to 7 am (night). With every measurement, students filled out a Google Forms with the email address, the number of decibels, the time and a picture of the measurement from the app.

For the statistical analysis, all the information in the Google Form was downloaded to an Excel file. The students, in groups of 4, calculated the mean, standard deviation and coefficient of variation of the measures per each time slot and made graphics (Figure 1).



	Mean	Std Dev	CV
Morning	39,04	3,67	9,41%
Afternoon	35,56	2,41	6,78%
Evening	35,63	2,95	8,29%
Night	34,27	2,97	8,67%

Figure 1: Results of the statistical analysis of one of Rubí's areas

With the analysis, students could contrast the hypotheses previously raised. They discovered, among others, that:

1. Two main parts of the city could be distinguished: the city centre (called "the red zone") and the outskirts (called "the green zone"), where the difference of decibels was notorious.
2. Some items not considered in the hypotheses could be identified; for instance, the proximity to children parks, which affected the amount of noise in the afternoon.
3. The Noise Map provided by the Town Hall had higher levels of noise in some parts of the city centre than those measured by students. As a possible reason it was pointed up that some streets had become pedestrian since the map was published in 2012.

Finally, to show the results of the study, the teacher selected the places where students had gathered enough noise measures (at least 70% of the number agreed in advance) and uploaded the results in a digital map provided by the Cartographic Institute of Catalonia, called Instamaps (Figure 2).

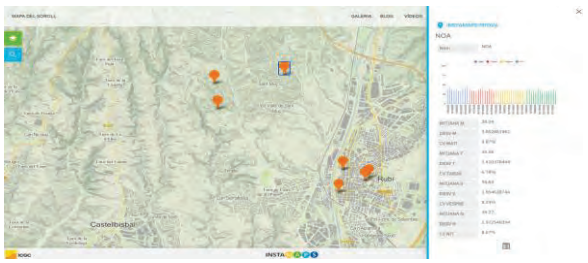


Figure 2: Instamaps of Rubí (www.instamaps.cat)[1]

Second part: How does noise affect our health?

The second part of the project followed the same structure as the first one and took place during the next 12 sessions. However, in this case, the previous study was carried out entirely by the students. In groups, they looked for information about how the noise affects our health and summarised it in an infographic made with Canva, which they shared with the rest of the students making an oral exposition in class. They then made their own hypotheses considering the previous research and gathered data in two steps. First, students, always in groups, proposed the type of questions they

[1] https://www.instamaps.cat/visor.html?businessid=b099e4b7093f76d5bf574d1e26dc4893&3D=false#14/41.5007/2.0225

should ask to the inhabitants of the city to study if the noise affected their health. Questions were shared in a padlet, commented in class to select the most suitable ones. Students administrated the survey in the two different parts of the city identified in the previous phase of the project: the city centre or red zone and the outskirts or the green zone. A total of 435 answers were collected.

Again, for the statistical analysis, all the information in the Google Form was downloaded to an Excel file and the students, in groups of 4, made a descriptive statistical analysis (Figure 3).

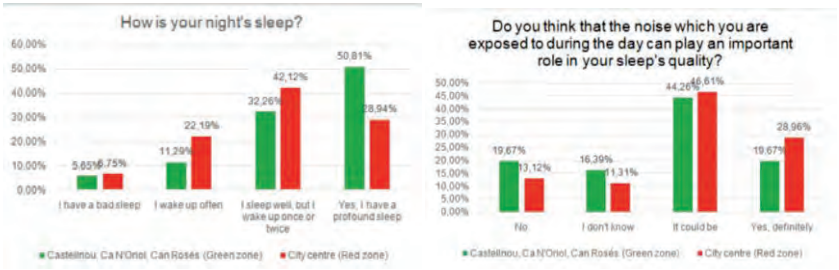


Figure 3. Examples of figures summarising two answers from the survey

As final results, students found that: most of the people were aware that the exposition to high amounts of noise for a long period of time could cause health problems; there was a difference between the people in the two zones in terms of their sleeping quality; and people suffered more from anxiety and stress than from physical health problems. At the end of the project, students made some general proposals to improve the noise pollution in the town, like installing porous paving which absorbs a high quantity of the acoustic wave, increasing the amount of pedestrian zones, organising workshops at schools, and using the local media (radio, magazines, newspapers) to make people aware of noise pollution and give advice on how to reduce the noise.

Analysing a teaching experience from a research perspective

Study and research paths as descriptive and analytical models

Researchers working in the Anthropological Theory of the Didactic (ATD, Chevallard, 2015) have been developing a methodology of analysis for teaching experiences that can be ranged into the category of inquiry-, problem- or project-based learning and are conceptualised as *study and research paths* (SRPs). These instructional practices correspond to the pedagogical *paradigm of questioning the world*, where one studies open questions and develops knowledge – with other kind of tools – to provide answers to them. Some difficulties found in implementing projects can be explained by the prevalence, at school, of the *paradigm of visiting works*, in which curricula are first proposed in terms of organisations of knowledge to study (or "visit") and problems, projects or investigations tend to be subordinate to them: one approaches a question – or carries out a project – to encounter some specific knowledge organisation.

As shown by Bosch (2018), SRPs are not only instructional proposals designed and implemented within the ATD, but they can also be used as *models* in the scientific meaning of the term: not examples to follow, but conceptual constructions to better analyse empirical experiences. The main research question motivating these analyses is to better know the conditions that can foster the implementation of project-based teaching and the barriers or constraints that hinder it. The set of conditions and constraints of all kinds (curricula and pedagogical resources, classroom management,

school organisation, society determinants, etc.) correspond to what we call the *ecology* of teaching and learning processes.

The study we present here is an example of the use of SRPs as a descriptive and analytical tool applied to an empirical teaching process organised in terms of project-based learning that was implemented by a teacher without any connection to didactics research, let alone the ATD. In fact, the teacher decided to teach statistics through projects without relying on any specific PBL perspective. Our purpose is to show some key elements of the teaching process – now interpreted as an SRP – that help to better understand its ecology. In the next sections, we introduce at the same time the notion of SRP and the analysis of the teaching process only for the first part of the project.

The Herbartian schema

In an SRP, the generating question is the main purpose of the inquiry. Students, guided by the teacher, address them by proposing new derived questions, searching data and pieces of information potentially useful, and studying them. The results of the study are then contrasted and validated with the data and old information available, which usually produces new interrogations calling for new data and information, etc. At the end, what matters is to be able to provide an acceptable answer to the initial question and disseminate it. The Herbartian schema proposed by Chevallard (2011) identifies some key elements of an SRP. The reduced form of the schema $S(X; Y; Q) \hookrightarrow R^{\heartsuit}$ indicates a didactic system S where a group of students X with the help of a group of teachers Y address a question Q to provide their own answer $R^{\heartsuit}$. The developed form of the schema $[S(X; Y; Q) \rightharpoonup M] \hookrightarrow R^{\heartsuit}$ includes a *milieu* M with all the resources used by $S(X, Y, Q)$ during the inquiry: questions Q_i derived from Q, external answers or works $A_j{}^{\diamondsuit}$ elaborated by others that seem useful to address Q, empirical data D_k and other pieces of knowledge, virtual and material objects O_m :

$$[S(X; Y; Q) \rightharpoonup \{Q_i, A_j^{\diamondsuit}, D_k, O_m\}] \hookrightarrow R^{\heartsuit}.$$

Some commonalities have been identified in the teaching experience:

- The starting point is an initial question, called the "generating question", the teacher raises in a global way, to the whole group of students.
- The project is a collective work, that is, the answer to the question is a joint report from the whole class, which will be submitted to the contest. Despite some of the work was organized in small teams, students share their results and the new questions or directions to follow.
- The work is guided through partial questions, with some given or requested answers.
- Several supports and tools were used: interactive maps, mobile applications, digital campus, etc.

Using the Herbartian schema, we have a single teacher $Y=\{y\}$, a whole class X consisting of students x_i sometimes organised in teams X_j. The generating question Q was divided by the teacher into two sub-questions: how noisy the city is ($Q1$) and how noise affects our health ($Q2$). Along the experience other questions, proposed by X or y, appeared and they were related to institutional answers $A_j{}^{\diamondsuit}$, (like the definition and measure of noise, or the statistical notions to determine a sample, organise data, summarise and visualise it, etc.). Material and digital tools were mobilised: Excel, DecibelX, Instamaps, Canva, GoogleForms, etc., together with the students' familiarity and knowledge about

the town and what produces noise. Finally, an important element of the project is the data collected D_k, linked to new knowledge work as its quality, reliability, representativity, etc.

However, an SRP is a dynamic entity where questions generate the need for answers with, in turn, raise new questions in a kind of selfsustained process (Bosch & Winslow, 2015). Next some examples are given, to show the dialectic between questions and answers and its crucial role in the dynamics of the process.

The questions-answers dialectic of the first part of the project

In an SRP many questions are raised, some more explicitly than others. Pieces of answers are provided to these questions, by the teacher or the students, using available resources or producing them by themselves. Space limitation only permits us to present a short account of the questions and answers that appeared during the first part of the project, those more implicit are indicated into brackets. We will next use this summary to analyse the teacher's and students' role in the inquiry.

Q1 Is Rubí very noisy?

Q1.1 What is noise and how to measure it?

→ A1.1 Teacher's presentation about noise A1.1.2 Introduction of the app DecibelX

Q1.2 [What do we know about Rubí's noise?]

→ A1.2 Official noise map of Rubí in 2012

Q1.3 Is the map still valid today? Can we reproduce it partially?

Q1.3.1 Where do we live in Rubí?

→ A1.3.1. We are distributed in different zones of the town

Q1.3.2 What are the characteristics of the surroundings of where we live?

→A1.3.2 Google Forms answering some questions

Q1.3.3 [How to collect data?]

→ A1.3.3 Using DecibelX in each student's zone in different hours, with a survey

Q1.3.4 How many data are necessary?

→ A1.3.4 Formula and determination of the sample size

Q1.3.5 How are we going to analyse the data?

→A1.3.5 With the mean, standard deviation, coefficient of variation and graphics

Q1.3.6 How many data do we have? How are they? Are there errors?

→A1.3.6 Data collection check

Q1.3.7 What do the collected data say?

→ A1.3.7 Data cleansing, numerical and graphical summaries, interpretation

→ A1.3 In some zones, Rubí is less noisy than in 2012 […]

Figure 4 shows the map of questions and answers only for the first phase, using the above notation.

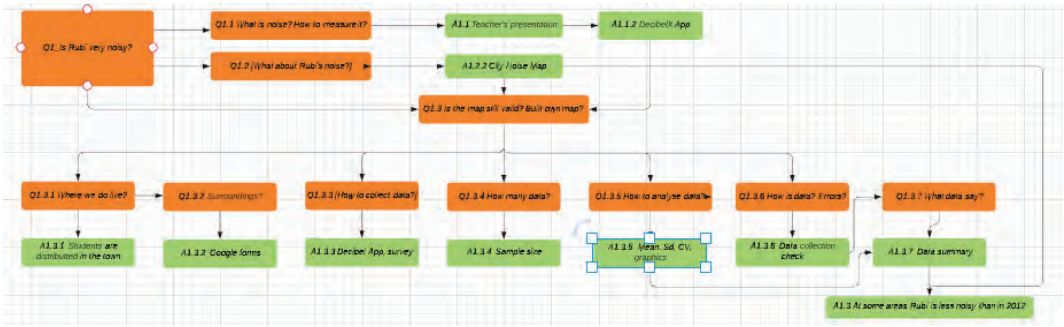


Figure 4: Map of questions and answers of the first part of the project

Some of the questions were proposed directly by the teacher, such as *Q*1.1 and *Q*1.2; few of them by the students. Some questions were answered using established works introduced by the teacher (the study dimension of SRP), while others need ad-hoc elaborations based on students' hypotheses, data compilation and exploitation (research dimension). The sharing of responsibilities between teacher and students was analysed. Table 1 summarises the involved elements (what), the class organisation (how) and the persons assuming the main active role (who) for the first 12 sessions. Remember that y represents the teacher, x_i individual students and X_j a students' team.

Table 1: Elements, methodology and main agent for the first 12 sessions of the project

#	What (elements)	How	Who	#	What	How	Who
1	Q1, Q1.1, A1.1, Q1.2, A1.2	Class	y	7	A1.3.5	Class	y, x_i
2	Q1.3, Q1.3.1, A1.3.1, Q1.3.2	Class + Indiv	y, x_i	8	Q1.3.6, A1.3.6	Class	y, x_i
3	Q1.3.3, A1.3.3, Q1.3.4, A1.3.4	Class	y	9	Q1.3.7, A1.3.7	Indiv	x_i
4	A1.3.2	Class + Teams	y, X_j	10	A1.3.7	Teams	X_j
5	A1.3.2	Teams + Class	X_j	11	A1.3.7	Teams + Class	X_j, y
6	Q1.3.5. A1.3.5	Class	y, x_i	12	A1.3	Teams + Class	X_j, y

The table shows that the teacher acted as main agent with a lot of active participation in most of sessions. However, an important characteristic of this project that is crucial in the paradigm of questioning the world is that all the new information, tools and pieces of knowledge introduced by the teachers were studied and activated by the students because they needed them to answer the question. The new knowledge was at the service of the project, not the other way round.

Concluding remarks

To analyse the constraints hindering the development of this teaching experience, we will consider two specific aspects. On the one hand, the experience was developed in response to a generic proposal, such as the announcement of a contest. The contest invites statistical work in the context of secondary education, as it is a topic included in the curriculum. The initial motivation of the contest is to influence the value given to statistics, especially its usefulness, to motivate students and get them interested in statistics. The generic recommendations and previous examples offered by the organisation of the contest include the case of formulating a question, a hypothesis or to do an experiment from which questions can be formulated. However, no detailed guidelines are given nor a specific PBL approach suggested; it is an open setting, passing the responsibility to the participating

teachers, which leaves them alone and requires much more dedication. It also gives them more flexibility and allows more creativity.

On the other hand, although it may be influenced by instructional formats that are in vogue, defined independently of the content, the teacher did not have guidelines to follow. The implementation of projects in class was not a requirement of the school. It appeared as the teacher's response to the demotivation detected in a group of students, with the aim to show the usefulness of statistics. The teacher worked alone to prepare the project questions and answers, provide the tools to be used and guide the students' inquiry. The result was clearly an excessive burden of time that puts sustainability at risk. The analysis of the project through the ATD approach shows some characteristics of the project that could have been organised differently, for instance in the management of the questions-answer dialectic and the sharing of responsibilities between teacher and students: what was explicitly stated, what remained implicit; what was done by the teacher, what by the students and why, etc. Collaborative work between teachers and researchers can help identify the constraints that hinder the long-term sustainability of project-based teaching in statistics and, the most important, implement new conditions to overcome them.

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