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# A multidisciplinary approach to model some aspects of historical events

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*This paper focuses on the problem of integrating a multidisciplinary approach to the study of extra-mathematical questions where mathematical modelling appears as a central tool in the teaching and learning processes. We present here the design, implementation and analysis of a sequence based upon a historical context, the war of Spanish Succession in Catalonia during 1714, which was implemented in two courses with 12–14-years-old students. We also show to what extent these implementations help to integrate an interdisciplinary study where history and mathematics will have to work together.*

**Keywords:** Mathematical modelling, inquiry, multidisciplinary approach, historical and cultural context.

## INTRODUCTION

The main aim of our research is to find complex situations of real life that can give rise to the design of a sequence of tasks that can promote inquiry and modelling students' competences. These real situations will be the origin of the design of a sequence of questions and tasks, integrating the necessary didactic devices enhancing students to mobilize the necessary cognitive processes to face them. More concretely: (1) to integrate diversity of tools coming from different disciplines and subjects and (2) to integrate mathematical modelling as an essential tool to facilitate a multidisciplinary approach to face such situations.

It is in this context of fostering the inquiry and modelling in which the selection of initial situations that will originate the process of design of tasks' sequences takes real importance. This situation leads to the formulation of the following specific research question that will be at the core of our research:

Given the classical description of contents of different subjects (Mathematics, History, Languages, etc.) at Secondary school level, and given the traditional isolation between these disciplines, how can we design didactic devices which locate problematic questions at the starting point of the study process where: (1) mathematics (and mathematical modelling) appear as fundamental tools to provide answers to them, and (2) can the mathematical study inhabit and interact with other disciplines (or subjects) to validate and enlarge the study?

Here we consider the particular case of Secondary school level. The sequence described in this paper was named '*Understanding the incidents of 1714*' ('Valorant els fets de 1714'). The main purpose for students (and also the final task) was to participate in a literary contest about the consequences of the war of Spanish Succession in Catalonia, which happened 300 years ago. Students were asked to face quite an open starting historical problem about this war. They had to begin by looking for real data in some historic resources, and to use mathematical tools for the analysis, understanding and looking for answers to some initial historical problems. Finally, they were asked to individually write a short story as means to share and officialise their final responses and conclusions about the consequences of the war. This short story was sent to a literary contest announced by a Catalan publisher<sup>1</sup> opened to all secondary schools.

In this paper we describe some of the main traits of the didactic sequence's design that was finally implemented. We also analyse how it contributes to the development of students' inquiry and modelling competences by using the talks' registers, productions from students and their answers to a final questionnaire, but also by describing the a priori mathematical and

didactic designs in which researchers and teachers work together.

## **THEORETICAL APPROACH**

In the design of the sequence of tasks different approaches interact. On the one hand, the mathematical and didactic design quality is justified based on the three criteria of didactic 'suitability' proposed by the Ontosemiotic Approach, EOS (Godino, Batanero, & Font, 2007): 1) the emotional suitability, 2) the epistemic suitability and 3) the ecological suitability. The aim is to design a sequence of tasks in which different suitabilities were included. For instance, its 'emotional suitability' can be justified by the fact that students were asked to participate in a literary contest from which some winners were selected (as it finally happened); its 'mathematical quality' (the epistemic suitability) can be justified based on the view that implementation allows students to trigger relevant processes of mathematical activity, in particular of mathematical modelling processes. In its turn, the 'ecological suitability' is justified by the fact that the curricula of these secondary-school students have a competency-based approach, where the teaching and learning processes provided by the curricula should promote competences to deal with complex and varied real-life situations.

These curricula guidelines are on the same directions of recommendations from other countries and international organizations like the National Research Council (NRC, 1996). For instance, according to the NRC, teachers should support the development of abilities of inquiry. These inquiry abilities are hardly related to modelling perspectives, and sometimes it is difficult to find the differences between both processes (Artigue & Blomhoj, 2013). A recent discourse of inquiry in mathematics education focuses on the use of methods and mathematisation processes, promoting the construction of mathematical hypothesis and models, and the need for arguing, valuing and controlling in an appropriate way to solve the contextual problem (Elbers, 2003). From our viewpoint, placing mathematical modelling processes at the core of activities involves promoting other kind of processes important in a rich and functional and mathematical activity (understood as mathematical richness of quality processes).

On the other hand, a way to get a high epistemic suitability is to design the sequence of tasks using the notion of study and research paths (SRP) (Chevallard, 2006; 2012) as a didactic device to facilitate the inclusion of mathematical modelling in educational systems, and more importantly, to explicitly situate mathematical modelling problems in the centre of teaching and learning processes (Barquero, Bosch, & Gascón, 2008). We assume and use the structure of SRP (Barquero, Serrano, & Serrano, 2014) as the main theoretical construct to design the didactic sequence we will present in this paper: (a) The starting point of a SRP will be a 'lively' generating question with real interest for the community of study (students, teachers and researchers); (b) During a SRP, the study of the generating question will evolve and open many others 'derived questions'. The study of all these questions will lead to successive temporary responses, which would be tracing out the possible 'routes' to be followed in the effective experimentation of the SRP; (c) The teacher will thus have to assume a new role of acting as the leader of the study process, instead of lecturing the students; (d) An important dialectic that will be integrated in the SRP is the task of posing questions and that of the continuous search for answers; (e) Against the temptation of imposing some answers that are acceptable within the educational institution, the group of students needs to be invited to defend the successive answers they provide; and finally (f) The dialectics between the media and 'milieu' will be also essential to control what exiting resources and answers are available 'outside' the classroom (in the media), but also what tools will help us to validate and integrate them in our study.

The proposal presented in this paper uses some historical contexts to develop inquiry and modelling competences in the same line as some previous works, for instance: Vilatzara Group (2003) used historical questions context questions to introduce mathematical modelling processes or Sala, Giménez, & Font (2013) proposed a selection of tasks in historical and cultural context to promote inquiry.

## **CONDITIONS OF THE DESIGN AND IMPLEMENTATION**

The starting question that opened the teaching sequence was placed in the context of Barcelona's siege during the war of the Spanish Succession.

$S_1$ : Which were the consequences of the incidents of 1714 for the society, culture and political organization of Catalonia?

Students were asked from the beginning to write a short story about the war's consequences for Catalonia with their own conclusions from their study developed in the classroom work. It was important this story was rigorous enough, based on contrastable historical data and involving a robust study about some related phenomena, like: Barcelona's demography evolution, economical changes for the society or for some guilds of the city, etc.

The teaching sequence was implemented during the course 2013/14 with two experimental groups at Secondary school level (12–14 years old) of 29 and 30 students respectively, in a high school in Badalona (Catalonia, Spain). Its experimentation was carried out during two weeks for each group, with a total of 7–8 weekly hours. One exceptional condition was that the subjects of History, Mathematics and Catalan literature were linked along this experimentation. They acted together in what was called the 'Mathematical-Historical workshop'. Along the workshop, the teachers of these subjects were all involved in the experimentation, with the help of the first author of the paper, who acted as observer and guide of the implementation. For their part, the students were organized in 'inquiry teams' that changed along the different stages of the workshop.

The study began describing the general initial situation  $S_1$  that was broken into some more concrete questions (some of them explained below) to better distribute and coordinate the inquiry-teams' work. They all began with the analysis of some real data (concerning each topic) in order to quantify and value the consequences of the incidents occurred in 1714 in Barcelona. Through the study of the initial question, together with the need of getting historical knowledge, evolved towards some other derived questions. The students had to search information outside the classroom in all available media (webpages, historical resources with real data, etc.). These teams had to build up and use different mathematical models to study some of these derived questions and to contrast the validity of their proposals by using tools from mathematics and also from history.

Most of the information related to the mathematical-historical workshop (initial worksheets, topics and questions to study, phases followed along the workshop, etc.), and also some of the results from its implementation, are available in the blog called 'Understanding the incidents of 1714': <http://valorar1714.blogspot.com.es/>. This blog was basically structured in four parts: a central part, where students could read teacher's posts with the aim of encouraging students to keep on working and temporizing each of the phases and tasks; on the right part, there were some materials and resources that students could use to do the first tasks of the workshop (historical frame contextualization). The left part contained the blog archive, the search bar, some links of interest and other resources 2.0 related to  $S_1$ ; on the top, four different boxes contained the worksheets grouped by topics and other documents concerning each of the topics. The didactic sequence was organised in the following stages:

*First stage: The historical frame contextualization.* Cooperative work teams (the so-called 'inquiry teams') were formed and each student assumed different roles and some concrete tasks. Students were also asked to individually sign a contract about the compliance of certain working rules. Each team prepared, exposed and defended a poster board) where they had to explain a part of the historical frame since the beginning of the war. The rest of the students had to listen to, question and assess the rest of the poster boards and presentations. After that, new couple-teams were responsible for carrying out a time line with the free software 'Timetoast' to ensure they had a clear idea of the chronology of the historical events.

*Second stage: Inquiry teams facing different topic related to  $S_1$ .* The students, organized in the inquiry teams of two or three members, focused on the study of some phenomena (proposed by the teacher) related to  $S_1$ . Some real information was also provided to allow students to initiate an accurate study. To begin, all the teams had a general introduction about data's origin, historical resources and some other information to contextualize the inquiry.  $S_1$  was broken into different lines of research that were grouped in three main topics: A, B and C. After the general introduction, the teachers, who acted as supervisors of the inquiry, assigned each topic to each of the inquiry team.

Topic A focused on the demographic dynamics of Barcelona' population before and after 1714. It was composed by four worksheets (one for each inquiry team):

$Q_{A.1}$ : Evolution of the population between 1600 and 1720;  $Q_{A.2}$ : Evolution of the births in Catalonia between 1600 and 1715;  $Q_{A.3}$ : Evolution of the illegitimate births between 1600 and 1715; and  $Q_{A.4}$ : Comparative study of the salaries and prices between 1680 and 1800.

Topic B focused on the study of Barcelona's guilds before and after 1714, composed by seven dossiers that introduced the question of describing and fostering the evolution of the following guilds before and after 1714:

$Q_{B.1}$ : The fishermen and sailors' guild;  $Q_{B.2}$ : The weavers' guild;  $Q_{B.3}$ : The wool crafters' guild;  $Q_{B.4}$ : The shoemakers' guild;  $Q_{B.5}$ : The tanners' guild;  $Q_{B.6}$ : The tailors' guild;  $Q_{B.6}$ : The 'blanquers' (another type of tanners) guild.

Topic C focused on the study about the changes in the configuration of the city before and after 1714, composed by two worksheets:

$Q_{C.1}$ : The construction of 'Ciudadella' (a citadel) and its consequences for the city;  $Q_{C.2}$ : Changes on the configuration of the city (Barcelona).

Each of these inquiry lines, starts with the contextualization of the particular topic included in the worksheet, which was structured in different parts (two at least) including questions from less to more complexity (all of these questions are available in the worksheets published in the blog). Students were always asked to add new questions to follow with their study, but some feasible questions were included in the worksheets to help teachers to guide the study. For instance, if we focus on the topic A -  $Q_{A.2}$  about the births' evolution in Catalonia between 1601 and 1700, it was introduced with the analysis of real data collected by Sant Just parish church (Barcelona) (Figure 1 - data provided by Ferrer, 2007). We began with the following general question:

Given the data of the number of births in Catalonia during some years before 1714, how can we describe the evolution of the number of births? Can

we identify any change? How can we make forecasts about the future number of births? How can we contrast prediction and reality?

Franges d'anys	Nombre de fills il·legítims
1601-1605	49
1606-1610	40
1611-1615	53
1616-1620	32
1621-1625	57
1626-1630	47
1631-1635	40
1636-1640	45
1641-1645	40
1646-1650	43
1651-1655	34
1656-1660	58
1661-1665	41
1666-1670	43
1671-1675	29
1676-1680	40
1681-1685	36
1686-1690	40
1691-1695	43
1696-1700	48

Figure 1a: Number of births per every period of five years

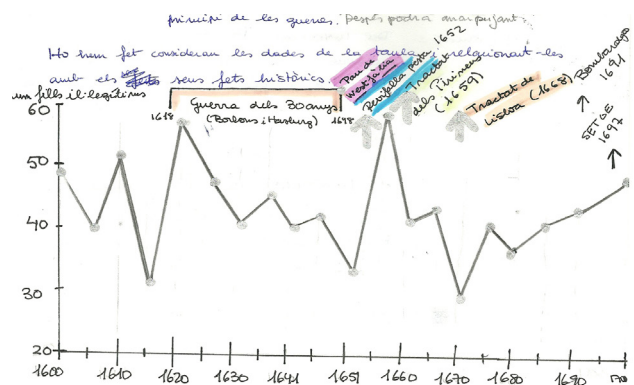


Figure 1b: Part of the partial report of an inquiry team working with  $Q_{A.2}$

The first part focused on facing questions concerning the description of real data about the number of births between 1600 and 1714, with some other questions about how to predict the births' evolution around to 1714. Most of the students began using the graphical representation of real data (see Figure 1b) to complement the numerical analysis and to describe, for instance: the year intervals when births increase or decrease, linking the growth description to some historical events, etc. Despite all the rich description most of the teams provided, mathematical tools were not rigorous enough to provide forecasts about the short- and long-term births' evolution. At the end of

the first part, students began to propose the use of discrete models (recurrent sequences models) or some basic continuous functions (constant or linear) to fit real data and also to predict birth's evolution. The second part expanded the previous answers and results. It was focused on creating tools to compare and contrast forecasts provided by the mathematical models with real data (more data about real births from 1714 were given to the inquiry teams). Furthermore, between the first and the second phase, each group had to prepare the 'interaction report' with which different teams working with similar topics (A, in this case) had to interact. From this interaction some common questions arise that could need some help from the teacher to follow with the activity (comparing proposals, introducing some unclear mathematical concept, formalising mathematical tools, etc.). At the end, each inquiry team was asked to complete, describe and report their work by writing their 'final report' about this line of research.

*Third phase: Sharing the conclusions from the inquiry teams.* In this final phase, each inquiry team had to prepare a presentation to share their study and conclusions. Some more 'interaction' moments were planned, depending on the conclusions they had found. For instance, it was necessary that some teams dealing with  $Q_{c.1}$  about the construction of 'Ciudadella' interacted with teams on  $Q_{b.1}$  about the changes on the guilds in the city. To better understand and explain why some changes in the city cause some movements in where guilds were placed.

Another example of the interlinked and necessary interaction between different lines of inquiry was shown by the work within  $Q_{c.1}$  (see Figure 2) and  $Q_{c.2}$  (topic C, Figure 3) about the creative proposals about the construction of the trenches (Torrás & Sobrequés, 2005). In the first phase of the study, each team focused on its own topic:

$Q_{c.1}$ : The 'Ciudadella' was built a few years after the defeat of September 11<sup>th</sup>, 1714 with a special architectural structure (Figure 2). What role do you think it had? What benefits could its architectural structure provide to the city (in military terms, protection of inhabitants, etc.)?

$Q_{c.2}$ : It's been documented that the structure of the trenches (Figure 3) during the War of Succession introduced some innovative changes.

What kind of novelties did this system include? What elements allow us to compare the shape of the trenches with the advantages in number of deaths?

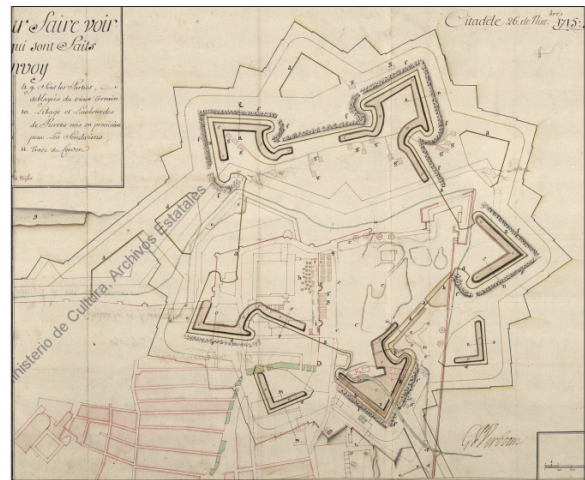


Figure 2: Part of the plan of the Ciudadella (1715).

Available in [http://ves.cat/19\\_P](http://ves.cat/19_P)

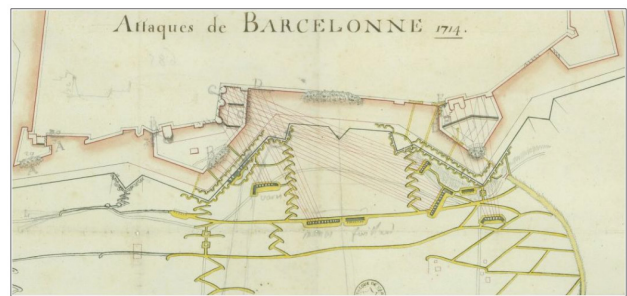


Figure 3: Trenches to the walls of Barcelona during the siege of the War of Succession in 1714.

Available from <http://gallica.bnf.fr/ark:/12148/btv1b7100421p/f1.zoom>

After each team developed its own study of their particular lines, some new questions were asked to link both lines. They mainly focused on studying the relationship between the structure of the 'Ciudadella' and the defensive strategy and the resistance capacity of the trenches structure to bear the continuous attacks during the siege.

At the end of this phase (as fourth stage), student had to individually draft a short story, based on the work done by all the groups working in the class, following the rules of the literature contest. After a process of co-evaluation of their writings, their writings were sent to the contest. The good news were that one of our students won the second prize of the contest (named 'Catalan memories'!)

## RESULTS AND DISCUSSION

In all the work developed around the initial situation  $S_i$  (what were the consequences of the war of Spanish Succession in 1714 to Catalonia) and derivative questions that characterize each topic, it was essential that the students assumed many responsibilities, traditionally assigned exclusively to the teacher. For example: work in a inquiry team; schedule their own study; discuss the proposals and results in the classroom; question the historical validity according to their answers; analyse real data and look for patterns to build models and make predictions; contrast their conclusions with the most appropriate experimental milieu (looking for data in external resources, trying with other models, etc.); summarize results and defend them orally and in writing; check the validity of the mathematical tools that are being used; raise new questions to continue with the study, etc. Moreover, students had to compare, search agreement with team members and also with other teams based on their own productions and results.

This way of working helped students to place themselves in a critical perspective towards the reality around them and gave them tools to come up with their own decisions and ways to analyse situations in our society (Vanegas & Giménez, 2010), like the initial situation we have presented in this didactic sequence. That is, despite the path of tasks planned and followed by the students in this implementation, the teaching sequence promoted autonomy and a critical thinking thanks to the openness of the questions.

Among other devices that were available to students and teachers, we emphasize the importance of the 'inquiry guide', and some documents that each inquiry group had to write so that the teachers could follow the progress of the study. These documents are: two partial reports (Inquiry teams had to fill them at the end of the first and second research phase respectively, presenting a synthesis of the issues treated, and explaining their responses and the mathematical tools used); an 'interaction report' between groups (it had to be completed to guide the interaction between inquiry teams); and a 'final report' that they had to write at the end of the study. This final report helped the students to individually write the short story to send to the literature contest.

However, we want to emphasize the importance of planning some sessions to share all teams' work and approaches with the rest of the teams. Students answered a questionnaire that allowed us to know their perception on various aspects of their learning. They said that they had had a lot of difficulties on: understanding in the beginning what it was being asked and why, integrating their contributions and results in their research, generalizing their results, synthesizing their work and writing the team's reports, etc. However, in general, their opinions were positive. It was in these 'sharing sessions' where the teacher had to act as guide or as mediator, helping students with all these new tasks that they had assigned.

Finally, we think that the final task of submitting an essay to a literary contest was a key element to engage students in the research project. Moreover, the integration and use of new didactic devices, as the ones described, that are not usually integrated in school reality help students to assume many responsibilities that are traditionally assigned only to teachers.

## FINAL REFLECTIONS

The research we have presented in this paper describes some of the characteristics of the teaching sequence of 'Understanding the incidents of 1714', which was designed giving an especial role to inquiry, modelling and the interdisciplinary approach. The design gives special importance to this interdisciplinary approach in order to allow students to consider mathematics, and specifically mathematical modelling, as a tool for finding answers to questions (in this case, from History). Besides the first resistances of students to use and mix tools and information from different subjects (history and mathematics, in our case), mainly doubting that teachers were 'asking' for this combined used, they could finally go into the 'dialogue' and interaction of such traditionally isolated disciplines. History was not only providing the initial context where the initial questions were posed, its tools were constantly integrated along the study to validate their responses. And in the same way, models and mathematical tools were at the disposal of the research activity, they had to help us to follow with our inquiry activity and all proposals had to be persistently checked with the appropriate historical-mathematical milieu.

Along the SRP students were asked to build up their own 'piece of history' through: the formulation of hypotheses based on the analysis of real data and historical information, looking for mathematical tools to enlarge the answers to historical problematic questions, contrasting the validity of mathematical tools with historical resources, posing new questions to follow with, etc. That is, as Dean (1995) describes, learning by 'doing history', approaching History as a scientific discipline but also, learning by 'using mathematics' as a fundamental tool to provide answers.

Finally, considering all resistances manifested by the students and also by the teachers facing this implementation, we plan to continue searching on what kind of new design and didactic devices are necessary to integrate this kind of studies in which a 'real study' of questions will require to combine and 'make' interact tools emerging from several disciplines, where, in particular, mathematics and mathematical modelling will have an essential role.

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## ENDNOTE

The rules to participate in the literature contest were available in the Bromera Publishers web: [http://www.bromera.com/tl\\_files/pdfs/altres/basesconcurso\\_cicatrius1714\\_doblepag.pdf](http://www.bromera.com/tl_files/pdfs/altres/basesconcurso_cicatrius1714_doblepag.pdf)