

Modeling in Mathematics and History as Teaching and Learning Approaches to Pandemics

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Abstract: The integration of innovative interdisciplinary approaches to the K-12 Curriculum aims to deepen students' knowledge and help them develop transversal skills. Applying an interdisciplinary lens, with a focus on pandemics, can help shape attitudes by means of inculcating the values of responsible global citizenship, and a high sense of personal and social responsibility. In the midst of the current lock-down due to Covid-19, a teaching approach to pandemics is presented, as an interdisciplinary connection between history and mathematics, based on the methodology of modeling in mathematics and the humanities. The main research questions posed: a) can modeling, as analyzed in the scientific literature, be used to interpret pandemics, e.g. in the case of the 'plague of Athens' (430 B.C.), as analyzed in the primary sources? b) Can the mathematical tools of statistical analysis be used to understand prevention measures through the centuries? Taking a longue durée perspective on history, students were asked to work on additional cases of pandemics across time and space, mobilizing both their mathematical and historical knowledge: process numerical data from primary sources, study maps, combine and compare elements of the past and the present using mathematical epidemiological models and real numerical data to study and predict the spread of infectious diseases. This paper presents the assessment of the effectiveness of this approach, conducted by means of closed and open questionnaires, administered in two phases (pre- and post-teaching) to a sample of 40 students aged 16-17 years. The results highlight statistics as a key tool for understanding real-world situations, and record the strengthening of students' knowledge in history, the raising of their critical thinking skills, as well as their enhanced ability to tackle real-world problems and understand responsible decision-making processes. Finally, the paper suggests that such good practices can prepare students for the complexity of globalized knowledge.

Keywords: Modeling, History, Pandemics, Mathematics, Interdisciplinarity

Introduction

This paper describes an interdisciplinary approach to teaching and learning about pandemics to 16 - 17-year old students at a Greek public high-school, by means of applying mathematical/statistical models for infectious diseases to historical material, i.e., data and information from primary sources, both textual and visual, graphs, maps, pandemic-related art. The key questions asked are the following:

- a) How can mathematical/statistical modeling be used to interpret pandemics of the present as well as the past?
- b) How can statistical tools be used to help understand the necessity of prevention measures through the centuries?

The effectiveness of the approach was assessed by means of questionnaires administered to the students pre- and post-teaching. The teaching approach gave rise to the submission of a new interdisciplinary curriculum on the mathematics and history of infectious diseases in Greek secondary education.

The teaching method adopted was a discussion-oriented flipped classroom: the students had to go through the teaching materials, answer the questions, and be prepared to participate in the discussion during the remote online class which took place online, on the platform of the European School Network on April 1st, 2020.

Purposes

In an effort to curb the spread of Covid-19, educational institutions all over the world strove to replace face-to-face instruction with remote synchronous or asynchronous instruction. Our research team consisting of three researchers from the distinct fields of Classics (Papadopoulou), Mathematics (Argyri) and STEM Pedagogy in Secondary Education (Smyrnaioi), following the motto that ‘crisis is a not-to-miss opportunity’, prepared and delivered an interdisciplinary lesson on the topic of epidemics/pandemics. Teaching pandemics as part of life in the present, as well as the past responded to the increased relevance of this topic. The teaching aimed to expand the notion of disciplinary literacy as set out by the state-mandated high-school curricular goals in mathematics and history taking into account the students’ set of critical and socio-emotional soft skills (Smyrnaioi 2020) as well as student work on the spreading of infectious disease spanning mathematics and biology (Askouni, Doulopoulou & Argyri 2020).

Outcomes

The outcomes of this effort are three-fold: first, a set of teaching materials (in Greek) including primary sources, exercises, and activities for the students. Second, an online student questionnaire consisting of 23 items combining a mixed approach (quantitative and qualitative) aimed at getting students to express their views on, as well as to evaluate the teaching. Third, a 103-page long syllabus on pandemics / epidemics (in Greek) submitted to the ‘Platform 21+ Lab’ project of the Institute of Educational Policy (IEP) (<http://iep.edu.gr/en/>; <http://iep.edu.gr/el/psifiako-aphoetirio/skill-labs>) (Smyrnaioi, Papadopoulou & Argyri 2020). Launched in the spring of 2020, this project of the Greek Ministry of Education aims to inform the Greek K-12 curriculum with the skills and literacies needed for students to keep up with the 21st century job market (OECD 2018). The curriculum submitted by our team falls under the thematic cycle entitled ‘I take care of the environment-Prevention and Protection from Natural Disasters’) and is to be implemented across Greek public middle schools in two phases starting September 2020.

Designing the approach

Key concepts

Modeling is a heuristic strategy in mathematics (Smyrnaioi & Weil-Barais 2005; Smyrnaioi et al. 2012) and in history (Leff 2003). Models play a central role in the mathematics of disease; therefore, the concept of modeling was central to the teaching. The SIR model is named after its three variables S (Susceptible), I (Infected), and R (Recovered). It is a simple way to illustrate the importance of social isolation for those infected. By staying at home, even before being infected, one moves directly from the Susceptibles to the Recovereds, without spreading the virus. Another fundamental parameter that governs the spread of diseases is the basic reproductive ratio, R_0 . The higher its value, the faster an epidemic will progress.

The SIR model was taught in the context of a case study on the plague of Athens (430 BC) illustrating the importance of social distancing measures and the catastrophic consequences of lack thereof. The plague in ancient Athens at the beginning of the Peloponnesian war against Sparta had spread uncontrollably due to insufficient knowledge about what were the best prevention measures. The students had to study the text of Thucydides, the historian, who survived the plague that clearly states that the plague was at its worst in the most densely populated areas, where people had sought refuge in order to escape the invasion of the Spartan army (Th. 2.52.1, see Crawley 2004). Also, the students were presented with estimates of different modern historians regarding the population of Athens and of the area within the walls inhabited by the refugees (after Patel 2019).

Content & Materials

The types of materials sent to the students prior to the instruction included primary textual and visual sources: infographics, charts, graphs, maps, and images and metadata of works of art inspired by infectious disease, openly accessible via Europeana (<https://www.europeana.eu/>), the biggest digital portal of cultural material containing over 50 million digitized resources from European cultural and memory institutions (galleries, libraries, archives, museums). The materials were organized in such a way so as to enable the students to refer directly to the tasks, when viewing the contents page.

Results

This section presents data collected by means of administering an open and closed student questionnaire consisting of 23 items pre- and post- teaching. The population sample was 16- to 17-year-old students of the Model School Evangeliki in Athens. It should be noted that public model schools in Greece recruit only high-achieving students after rigorous examinations.

Our survey consists both of quantitative and qualitative items, so as to get deeper and far-reaching results. To all intents and purposes, the adoption of a mixed methods approach combining quantitative and qualitative items increases the usefulness of the findings. The originality of our approach counterbalances the limited number of respondents. This in our view, is the main limitation of the conducted survey in terms of generalizability and external validity of the results.

Part 1 of the questionnaire (accessible online here: <https://www.surveymonkey.com/r/7D3XWTH>) consists of seven questions, of which three are closed-ended. Question 1 sought information about whether the students wanted to study a) mathematics/science b) humanities/social sciences or c) Not decided yet. The majority responded that they wanted to study mathematics/science (18.4%). The second choice was humanities/social sciences (7.25%). 11% responded that they had not decided yet.

Question 2 sought to reveal the students' expectations, which were: a/ linking mathematics to the humanities/history; b/ historical information about pandemics; c/ mathematical modeling/mathematics of pandemics; d/ new knowledge e/ knowledge about pandemics; f/ protection measures against pandemics.

Question 3 asked the students to state their reason for attending the lesson. 36% stated that it was because they loved mathematics, 14% because they were on good terms with the instructors (the corresponding author for history and the second author for mathematics), 3% said that was because they loved history and 11% for no particular reason.

Question 4 asked: 'How many times have you been taught interdisciplinarily/multi-disciplinarily?' Most of the students responded that had been taught interdisciplinarily twice before. The second most frequent answer was that they had not been taught interdisciplinarily before.

Question 5 asked the students to give examples of connections between positive studies (mathematics, physics, chemistry, etc.) with the humanities (Greek, literature, history, etc.). The students' responses highlighted chemistry, radiochronology, in particular, and its relation to archaeology:

Question 6 asked for the students' input in regard to cross-curricular connections between mathematics and history. The responses highlighted stereometry, statistics, algebra and analysis.

Question 7 focused on student perceptions on incorporating more cross-disciplinary content between the human sciences and the exact sciences into their learning, because it... a/ helps one become well-rounded; b/ prepares for real life; c/ helps bridge the gap between the 'hard' sciences and the humanities/social sciences; d/ expands knowledge; e/ promotes better understanding within subjects; f/ enhances skills; g/ provides motivation; h/ can provide a link with higher education.

Part 2 of the questionnaire consists of 6 items, of which only 2 are closed-ended. Question 1 asked the students to 'record the knowledge gained in history'. The students' answers focused on the following:

a/ knowledge of pandemics of the past and ways to deal with them then; b/ chronology of the epidemics - pandemics that have affected humanity to date; c/ the positive effect of popular perceptions about preventive measures against pandemics'; d/ about John Snow and how he helped the English people cope with a major epidemic'.

Question 2 asked the students to record the knowledge gained in mathematics. Their responses mentioned the following: a/ how to calculate the transmissibility of a disease; b/ greater familiarity with charts, recognition of exponential difference from the logarithmic model; c/ an idea about statistics and how diseases and pandemics spread; d/ which models describe the real situations more accurately and realistically; e/ the exponential and accounting function as well as for the normal distribution.

Question 3 asked students to qualify the connection between mathematics and history in a 5-point scale and their answers are as follows: extremely interesting 34%, very interesting 33%, somewhat interesting 25%, not so interesting 8%, not at all interesting 0%.

Question 4 asked the students' opinion in regard to the quality of the teaching. Half of them replied that it was of 'high quality' (6/12), one replied that it was 'very high quality' (8.33%), five replied that it was 'neither high nor low quality' (41.67%).

Question 5 asked the students to write any suggestions for improvement of the teaching. Their replies included quantitative suggestions: asking for a/ more material, b/ more mathematics, c/ more case studies) and qualitative suggestions concerning the teaching and the online platform.

Question 6 asked the students to give suggestions and specific examples as to how the curriculum could include more lessons/topics making interdisciplinary connections between mathematics and history. The students' replies pointed at the history of mathematics.

Part 3 consists of eight questions on the skills improved (accessible online here: <https://www.surveymonkey.com/r/V6F27WG>). According to the students, the skills ranked on a 1-10 point Likert scale, as follows: analyzing information (87%), critical thinking (85%), ability to make reasoned decisions (81%), creativity (81%), intercultural understanding (77%), flexibility-adaptability (76%), organizational skills (69%), self-awareness/self-knowledge (60%). The final questions asked the students to rate the improvement of their knowledge in mathematics, history, and in regards to their attitude and motivation toward learning. Their responses are 66% (improvement in knowledge about the mathematics of pandemics), 80% (improvement in knowledge about the history of pandemics), and 86% in terms of their improvement in motivation toward learning.

Discussion & Conclusions

This paper presented an innovative teaching approach on pandemics/epidemics from an interdisciplinary perspective combining the mathematical modeling and the history of infectious diseases. Novel teaching/learning materials were developed and administered to the students prior to the teaching. This took place as soon as the schools transitioned to remote classes in order to prevent Covid-19 from spreading. The approach was evaluated both quantitatively and qualitatively. This mixed methods approach produced interesting results, especially with regard to the students' opinion about the interdisciplinary approach.

The most striking findings of the survey resulted from the qualitative data collected. The students expressed their enthusiasm with quite lengthy replies giving compelling reasons for the necessity of interdisciplinarity in teaching and learning. The students were intrigued by the topic and asked for more teaching/learning on this topic. They reported that the case studies using data about historical periods in order to practice mathematical content knowledge had enhanced their learning in both mathematics and history. From the different pandemics across time, they were very keen on further investigating the case of the cholera outbreak in London in mid-19th century and its curbing thanks to mapping of the affected neighborhoods by John Snow. Also, most students responded that they were interested in pursuing studies in a field related to mathematics rather than history, and answered that they had coped better with new knowledge in history, rather than mathematics. Last but not least, the students reported their greatest improvement in the 'critically engaging with information' category, a skill which is in great demand in today's knowledge-based societies.

Despite the relatively small number of respondents, these results suggest that such interdisciplinary approaches are good practices that can prepare students for the complexity of globalized knowledge. In the coming academic year, the new interdisciplinary curriculum entitled 'Mathematics teaches...History interprets' that is based on the teaching approach, will be piloted in schools across Greece, so that it can be fully implemented country-wide in 2021-2022. It is aimed to equip students with both the knowledge and skills necessary to navigate natural disasters and global health issues in the 21st century.

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