Original Research Article

"statistics4school.eu": A Novel Educational Web Platform for Statistical and Geospatial Learning

ABSTRACT

Statistical literacy is of the utmost importance in modern societies traversing the era of Big Data, where virtually everyone has access to a tremendous volume of information but, at the same time, only a very limited percentage possess the ability to process and comprehend. There is no doubt that it is challenging to collect and use up-to-date statistical information in problem-solving when dealing with complex datasets. Moreover, cannot talk about statistical and data literacy without mentioning spatial thinking development and Information and Communication Technologies (ICT) use. So in the paper we present the web-based platform, *statistics4school.eu* which designed and implemented to bridge the gap that there are neither any free online educational tools for statistical analysis available for the Greek language nor are there any that can produce visualized messages based on the geography of individual Greek regions and sub-regions, in a way that can be readily facilitated in the classroom.

Keywords: statistical literacy, visual literacy, spatial thinking, geospatial technologies, web-based platform

1. INTRODUCTION

Searching through 'The Web' and its services – the Encyclopedia of today - yields a sizable volume of data and information – giving birth to the need to categorize, correlate, analyze and ultimately utilize them. In order to implement this procedure in a thorough and methodical way, the bulk of retrieved data must be viewed through a new context of processing, evaluation and presentation. In the first stage of processing and evaluation of 'raw data', Statistics plays a crucial part with the tools it has to offer. Presently, the teaching of Statistics is subject to constant research, mainly due to the prevailing trend to radically reform the Curriculum in Mathematics across all grades of education [1-11].

The general approach to help students get a firmer grasp on the rather 'abstract' statistical functions is to employ various methods of visualization (through tables, graphs, etc.). Nowadays data visualization is actively under research, but we are not far from the truth when we assume that this is yet another kind of literacy [12-14]. Thus, as it has long become a priceless tool when comparing and understanding data which originate from multiple and frequently heterogeneous sources, with the aim to create suitable conditions to reach safe conclusions and make educated decisions, while minimizing risk factor [15].

Visual literacy contributes in achieving these skills and is considered by many to be one of the most significant literacies of our time [16-20]. Individuals who develop the skill of spatial perception in addition to their visual literacy can think in pictures, i.e. represent information in planar and temporal means. Based on this, contemporary students are invited to cultivate skills associated with the ability to interpret, critically evaluate and create visual messages [21]. Through this, their education performance improves and concepts that are hard to conceive become more intelligible. At the same time productive thinking and the ability to express argumentative speech is bolstered, via the identification of obstacles and limitations arising in each situation they are faced with.

Neuropsychology research showed that acquiring the ability to process spatial information is essential in order to better understand numerical magnitudes, also pointing out possible benefits that may be reaped from its early development [22-23]. According to [24], spatial thinking is heavily based on the use of maps, graphs, pictures, charts, models and other depictions. Additionally, it supports the description, explanation and discussion of facts, structures, relations and functions of a great variety of spatiotemporal procedures.

The visual representation of statistical data using a combination of geospatial backgrounds and modern multimedia means (e.g. virtual globes, video projectors, interactive whiteboards etc.) constitutes an intuitive method of delivering the former to the average user, aiding them to better grasp its meaning and put it to good use when they need to make decisions based on it [25]. Visual literacy is a valuable assistant in the pursuit of properly assessing statistical information and constructing valid data presentations [26], owing to its multi-disciplinary nature [27]. Taking into account the increased demand for cartographic backgrounds [25] that many taught courses present today (e.g. history, geography, environmental training, social sciences), we can't be far off to expect the inclusion of Geographic Information Systems or GIS to play an integral role when shaping the manner in which these courses are taught. Adaptably, the expanded usage of GIS over the past few decades in many professional and scientific areas besides that of social sciences, only serves to highlight the significance of these systems as a decision making tool [28-30], as well as the demand for people who possess the skills and knowledge to use them [31-32]. According to [33], geo browsers (such as Google Earth) have developed a new type of GIS, making spatial data available to a much wider range of people than before, but there are also enough arguments in the direction of how harmful the use of geo browsers can be to the development of critic spatial cognition skills.

Over the past several years, researchers, teachers and software developers have set their focus on the design, testing and evaluation of geospatial technology and how to best incorporate it in the area of education [34]. Using Geography as a stepping stone to present Statistics in class with the aid of ICT, is today's trend. Geospatial technologies, or GST, are broadly used in a multitude of aspects in social sciences (economics, humanitarian studies, archaeology, geography, etc.) as well as in most contemporary educational systems [35-36]. This is owed to their high development rate and bloom in recent years, and their diffusion across a variety of fields [37]. So it stands to reason that when we talk about visual representation and spatial analysis, assets like GPS, GIS, Remote Sensing, cartography, etc. are also part of the phrase and equation [34, 38-41]. By employing social sciences like geography as a framework [42], GSTs contribute to the students' skill honing in new and innovative ways. This is accomplished through bolstering attitudes and behaviors which are closely associated with their ability to learn [43-44], while at the same time leading to the development of spatial thinking and reasoning [45-47].

ICT literacy leads in the development of skills high in demand in our era of information. The skill to use digital media with the same ease as we perform 'computational' thinking provides the tools we need to construct the knowledge required to solve problems within the digital world we live in [48]. Since their very earliest steps, the versatile ICT facets play a decisive role in promoting changes in the education system, serving as both a footing and a positive drive in this direction [31-32,39,49-50]. Students of today have been brought up surrounded by technologies such as computers, tablets, smart phones, PDAs etc., all the while using social media networks and other messaging applications to reach friends and relatives, on a day to day basis. Additionally, the importance and effectiveness of incorporating ICT (e.g. GIS, training software, hypermedia applications, virtual environments etc.) in the tutoring process cannot be overstated enough [51-52] when it comes to enhancing spatial thinking.

Last but with no lesser gravity is the field of Geography. Geography teaching supports cross-curricular teaching methods. It implements cooperative and productive learning principles, while at the same time it allows students to acquire values and abilities that will help them become cognitively aware and develop their psychomotor competences or activities [53].

From all the above we can see why GSTs with the aid of Geography and ICT can fill the shoes of the framework we need to manage statistical data in a rational and appealing way. The combined use of maps and geospatial information can be a valuable assistant when it comes to presenting the full picture Statistics aims to draw, in the most efficient of ways [53] – and vice versa: Geography often welcomes the help of Statistics when it aims to give presentable results. The significance and importance of employing a geospatial background for statistical information presentation lies in the fact that this background has a direct connection to the very meaning of the information (i.e. its semantics) rather than its syntax or structure. The interaction and interconnection between statistical and geospatial data in real time, unmistakably leads to the development of the students' visual and geospatial cognition, as it piques their interest and focus in a very creative manner.

In this paper we present a digital tool -created for PhD purposes with the exclusive use of Free Open Software (FOSS) –aimed at both teachers and students alike, focusing on GSTs. The adaptation of this web-based platform will provide them both with means to represent and manage real statistical datasets, offer the opportunity to use simple statistical and/or mathematical functions as well as a tool to visualize these against the geospatial backdrop of Greece – at the top level of Administrative Regions (Prefectures) or Municipalities. It also features ICT-teaching scenarios sharing for the purposes of interdisciplinary teaching, as a pedagogical practice to combine Statistics with other learning subjects. The method used to complete the activities was based upon student-centered guided exploratory learning and collaborative teaching. A worksheet with the activities and an instructions sheet were distributed to the students. The ICT part included the computer lab equipment, i.e. PCs with internet connection, a video projector, a printer device and an interactive whiteboard.

2. DIGITAL PLATFORM

2.1 Statistics4school

The goals of the digital web-based platform we created are twofold. Firstly, the tool should be easy for its intended users to pick up and put to use, effortlessly and quickly, without any prior specialized knowledge. Teachers will be able to mediate students' knowledge about statistics with a more positive and adequate way through collection, interpretation and evaluation of such information. Moreover, even students with varying competence levels in reading, understanding and presenting information will be able to manage statistical data taken either from a database like Hellenic Statistical Authority (ELSTAT) or from field survey, to instruct, interpret quantitative analysis respectively and visualize them with the aid of simple graphs and maps. Secondly, it was our intention to demonstrate that through the adoption of ICT, educators can create teaching material tailored to their classroom session needs, with relatively minor effort.

In Greek Geography's curriculum for the 5th grade of elementary school there is an extensive report about Greece (Unit A - *The maps. A tool for studying the world*, Unit B - *The natural environment of Greece* and Unit C - *The anthropogenic environment of Greece*). In the 1st grade of high school, in the 1st chapter students "learn" about the use of maps again and in the 2nd grade there is a reference in some chapters to statistical data, through tables, e.g. Section 3, Chapter 39 [54-55].

In *Photodentro* and *Aesop* – official repositories developed and maintained by the Greek Ministry of Education and Religious Affairs - there are many activities that use the map of Greece in its entirety. There is no tool, however, that can fully serve the purposes of management, analysis, interpretation and visualization of statistical data through functions, graphs and, most importantly, maps which employ the geospatial background of the various individual administrative sub-regions of Greece – Municipalities and Prefectures.

The web-based platform *statistics4school*, fully created with the aid of Free Open Software (FOSS), combines tools for elementary statistical data analysis and aims to help with the cross-curricular Statistic approach to other subjects. These data may originate from a number of relevant online databases and pertain to statistical facts of everyday life in Greece. Its main function and layout bears strong resemblance to another online open-source project, created with a similar purpose in mind, namely *i-use*, which served as one of our main inspirations. However, as stressed above, there are neither any free online tools for statistical analysis for education available in the Greek language nor are there any that can produce visualized messages based on the geography of Greek Regional authorities and sub-regions, in a way that can be readily facilitated in the classroom. To bridge this gap we designed and implemented *statistics4school*, from scratch, as presented in the following sections.

2.2 Design and implementation

The development of the digital web-based platform followed the **ADDIE** instructional design model (**A**nalyze, **D**esign, **D**evelop, **I**mplement and **E**valuate) [56]. For the first part, we conducted a survey with the aid of an online questionnaire we created which ran from January till March 2018, in two hundred eighty five (285) secondary education level schools throughout Greece. In this survey [10], one of the primary research questions addressed was the issues teachers consider when it comes to putting such platforms in use – either in the classroom or when planning out their courses and preparing their teaching material in advance. The key factors, in both cases, were *time* and *trust*. The first involves the time investment (to prepare and possibly become fluent in it, if not already trained to the use of such web-based platforms) and time allotment (for employing the prepared materials, called scenarios, in the classroom). In the matter of trust in cloud-based services, it was not surprising to find that the younger and/or more ICT skilled respondents felt more relaxed and confident in using them. Finally, we queried them regarding the conditions they thought were unwaveringly important, in their opinion, in order to use such online platforms. Their top responses included information security and anonymity, as well as required equipment availability.

Following up from this and taking their opinions and expectations to heart, we proceeded with the design and implementation of the tool itself. We looked into two alternative architectures, namely Client - Server [57] and Browser – Server [58]. Given the fact that we wanted to create an installation-free web-based platform which should be easy for one to manage and one-click accessible by the end user, completely open source but without compromising security or efficiency, we decided in favor of the Client – Server architecture. However, in order to shorten the development time and also ensure increased compatibility, we decided to use a 3-tier variation of this architecture. Specifically, besides the discreet Client and Server parts we also have a standalone Database Server layer. Of these 3 we implemented only the Server layer, while employing existing software for the other two (Figure 1).

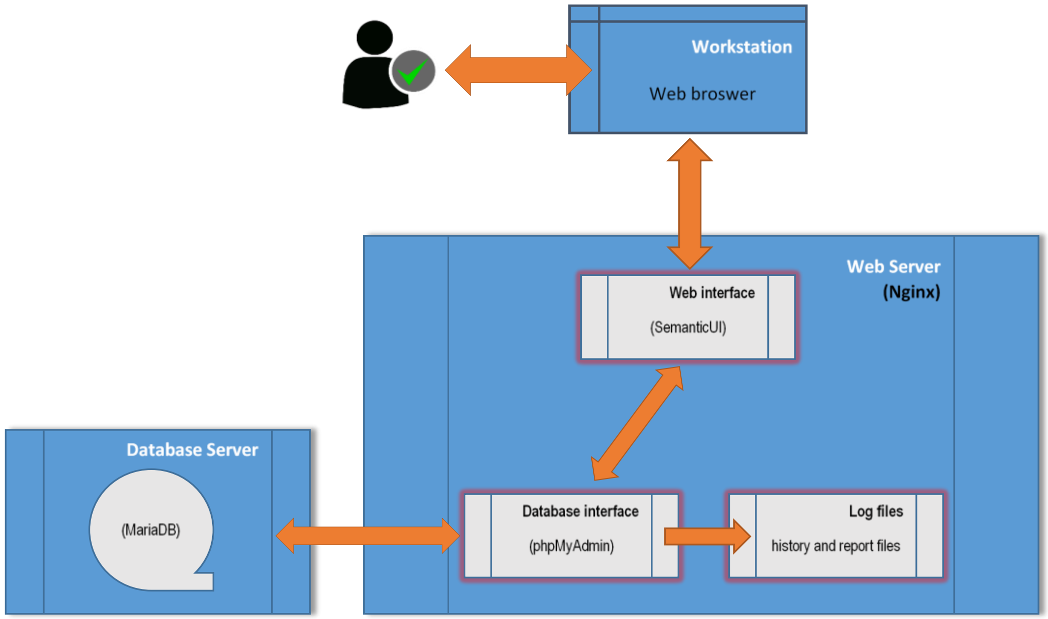

Fig. 1. 3-tier Client-Server Architecture

Our Server implementation follows the MVC architecture (Model, View, Controller), according to which there are 3 discreet modules with each one being responsible for a different function. **Model** represents the part where the communication between the Server and the Database takes part, to mine data. **View** receives (these) data and determines the instructions (html/css/js) to be sent to the Client in order for it to properly display the application's output. Finally, the **Controller** handles the communication between the Client and the Server, ensuring that the appropriate data are received and the suitable 'view' is called, according to the received request. It is worth noting that in our implementation both the Web Server and the Database Server are hosted ('run') on the same terminal.

The implementation of the tool itself was done using FOSS, exclusively. The software candidates we considered, besides being free-to-use, needed to score very high marks in terms of security, customizability, support and popularity. Having considered all these, we decided to use the following applications and suites:

- *Django* – our Python-based framework,
- *MariaDB* – MySQL successor, for database management,
- *Semantic UI* – for the interface (HTML/JavaScript),

- *PyCountry* – ISO codes for the Greek geospatial region names (Prefectures and Municipalities),

- *Chart.js* – ready-made JavaScript modules for the creation of graphs, and

- *NGINX* – a modern, alternative Apache server

We abided by most of the best practices suggested by Django, a framework famous for its robust security structure. On top of it, the default security features provided by NGINX were employed. Lastly, the only explicit measure taken in the module that handles the user uploaded content is one to prevent DoS (Denial of Service) attacks. As this content (teaching scenarios) are shared under the Creative Commons license and no sensitive personal data are stored on the website, we decided it was not necessary to have more explicit tools in place.

The interface itself, i.e. the webpages layout, menu and button labels clarity and on-screen displayed information, was kept simple while at the same time intuitive to understand and put to use. Naturally, whether this goal was achieved or not would need to be put to the test, through evaluation by both the teachers and the students.

The tool can be found at the URL *statistics4school.eu* and currently is in Greek only, as per the original target group. In the brief introduction that follows all menu titles, labels, captions etc. are collocated in parenthesis translated as well, for better readability (Figure 2).

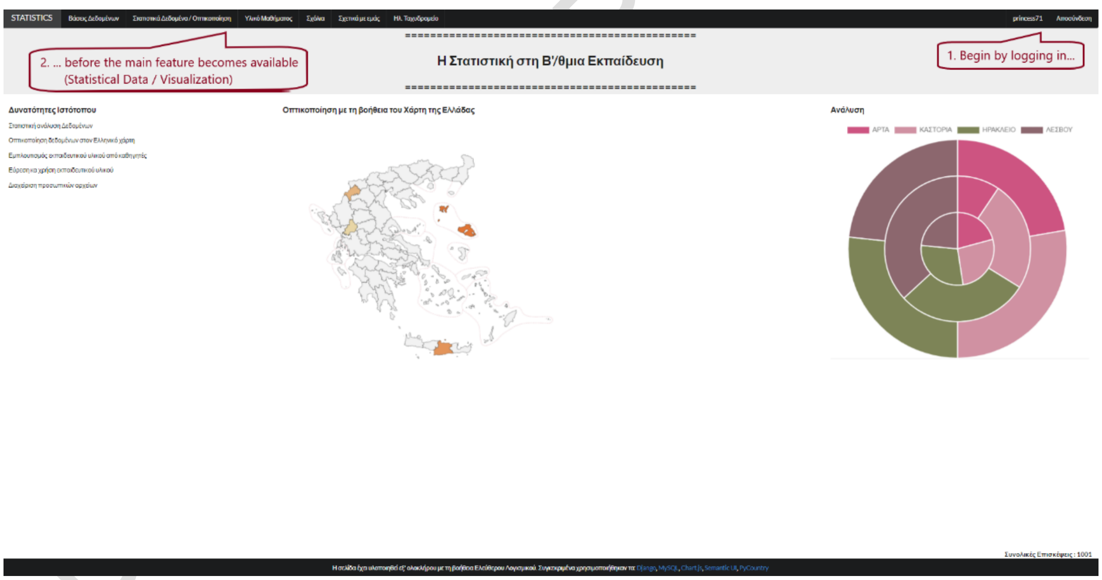

Fig. 2. Main Page

Βάσεις Δεδομένων (Databases). There are links to various open databases here, alongside a brief description to each one's scope. The five databases that are featured here at the moment are World Bank, Eurostat, GapMinder, Hellenic Statistical Authority (ELSTAT) and Open Geodata of Greece.

Στατιστικά Δεδομένα/Οπτικοποίηση (Statistical Data/Visualization). This is the platform's main functionality's home page. Complying with the unanimous reply of the survey responders that the platform's main tools should only be accessible to registered users (for reasons of *eponymity*), one is required and prompted to log in to the web site before they can visit this web page. Registered users will find here the tools to manipulate and visualize their statistical data in Figure 3.

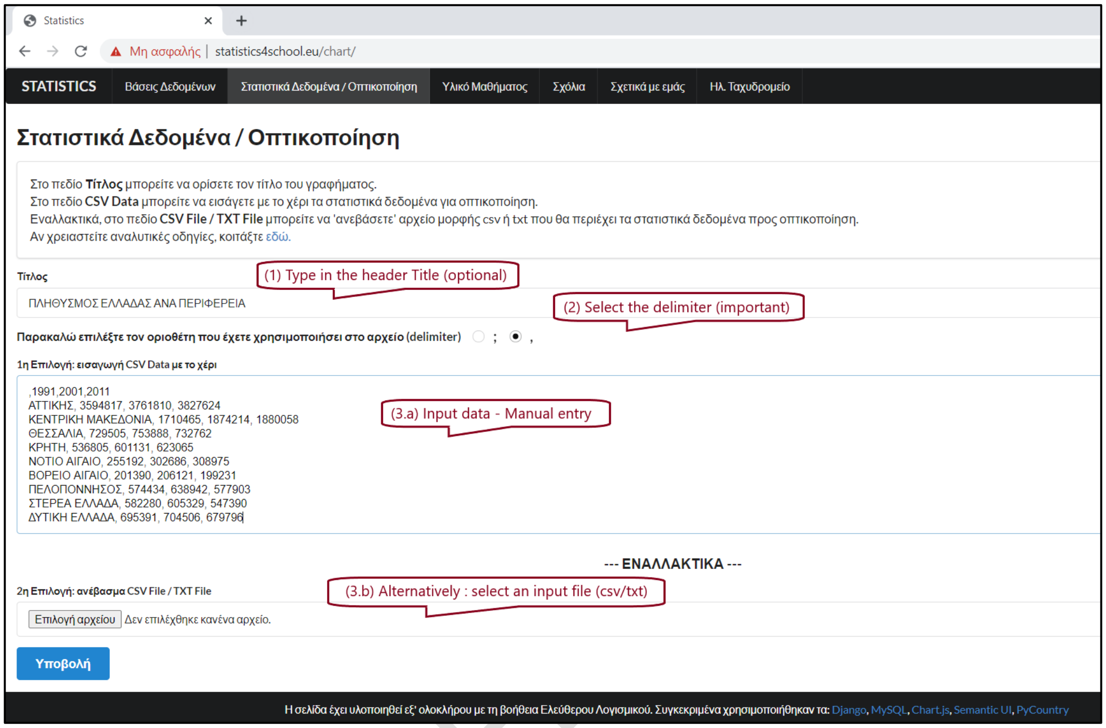

Fig. 3. Insertion of statistical data

These may be submitted in either of two ways: one can enter them manually, by typing them in, or they can select a premade .txt or .csv file. The syntax is common in both cases and easy to learn, as demonstrated below; it is further explained in an instructions file which may be downloaded on this page. The most important thing to note is the delimiter selection (step (2) in Figure 2 above), as it impacts the correct parsing of the input data:

,1991,2001,2011

ΑΤΤΙΚΗΣ, 3594817, 3761810, 3827624

ΒΟΡΕΙΟ ΑΙΓΑΙΟ, 201390, 206121, 199231

etc.

- the first line starts with the delimiter (here, we opted for the comma) and it contains the names of the data table 'columns', e.g. the years
- the next lines correspond to the data table 'rows', i.e. the statistical measurement value; each line begins with the name of the region, followed by the value that corresponds to the respective 'column' – e.g. first year, second year, etc. This means that if the 1st line of input data contains, say, three values, all lines after this will contain four.

Once the statistical data are submitted (blue button) they are presented on a new page, in table format in Figure 4.

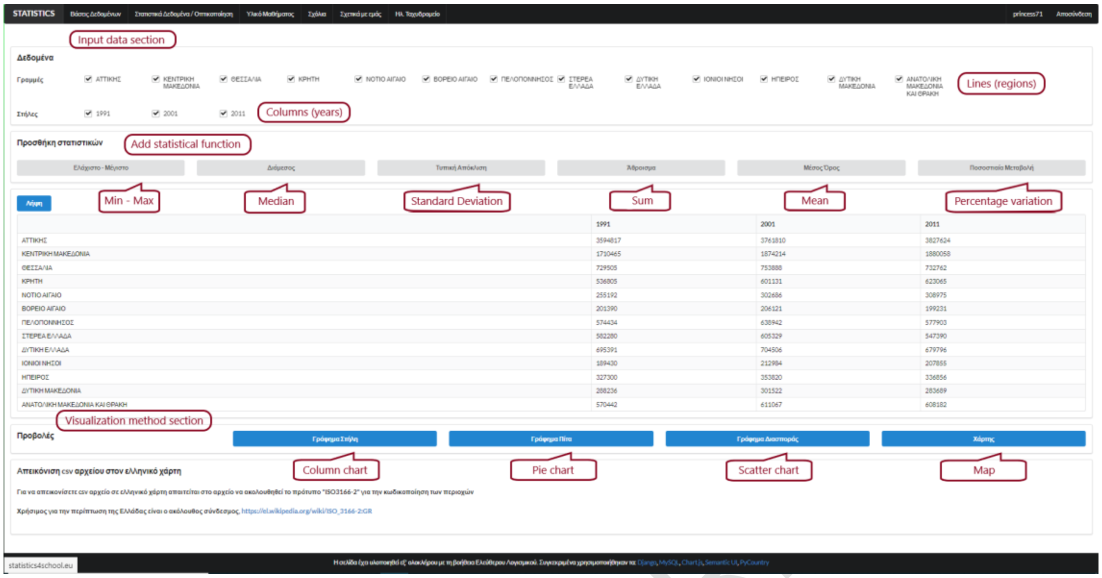

Fig. 4. Table format, Statistical functions and Visualization features

The page is divided in a number of discreet sections. At the very top we find the *Input Data section ('Δεδομένα')*, wherein our input values are sorted in lines and columns. Ticking or unticking any box will add or remove the respective value from the set to be processed below.

The next section (*'Προσθήκη στατιστικών'*) is where we select the desired statistical function(s) to be calculated and displayed. Columns are added and removed with each consecutive clicking of these buttons (toggle mode), containing the respective values, displayed in the table directly below. Currently, we opted to implement only those that appear in the Greek Curriculum, namely *Min-Max*, *Median*, *Standard Deviation*, *Sum*, *Average* (aka Mean) and *Percentage Variation*. It is however entirely possible, with some effort, to add any function one needs by modifying the underlying code. It is, after all, an open source platform.

Finally, just below the table of statistical values, lies the Visualization method (selection) section (*'Προβολές'*). Four depiction methods were selected, based on their popularity and frequency of use in Greek classrooms. From left to right, these are (blue buttons): *Column chart*, *Pie chart*, *Scatter chart* (Figure 5) and *Map*.

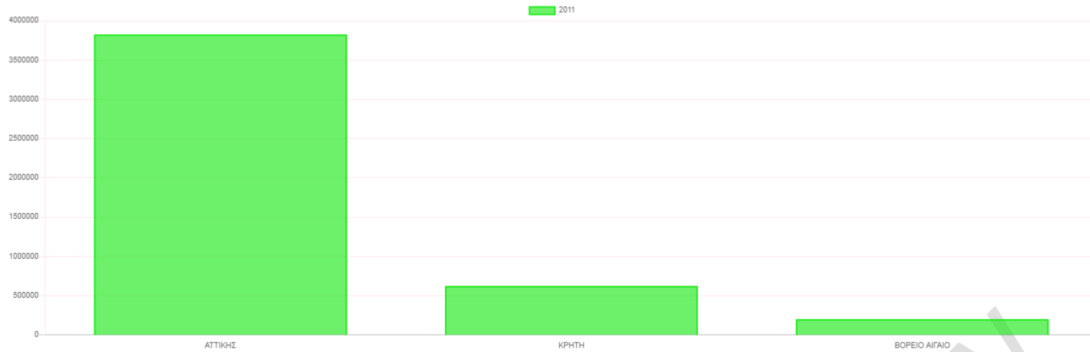

Fig. 5. Example of Column Chart visualization (3 regions, year: 2011)

Arguably, the least common one – and our main feature as well – is the last one. It is for this reason that it is presented extensively in the next section.

Υλικό Μαθήματος (Teaching material). This is the platform's second main feature's home page. Here someone can find fully augmented ICT - teaching scenarios with ready-made statistical data, teaching scenarios, activities-worksheets, .kml files as well as guidelines for how they can make use of all these on digital platform. They can download them and use them, freely (Creative Commons) in class or upload their work, to be shared with other individuals – be it teachers or students.

Σχόλια (Comments) & ***Σχετικά με εμάς (About Us)*** are pretty much self-explanatory.

2.3 Geospatial background

The use of the map of Greece as the geospatial background for the presentation statistical data pertaining to everyday life (ELSTAT) at the levels of either Prefecture or Municipality was selected in order to fill the existing presentation gap in this area.

Following up from the platform presentation in §2.2, clicking on the rightmost button (*'Χάρτης'*) brings up a new window, like that in Figure 6 below. With the aid of the *PyCountry* library which provided us the ISO databases for the countries standards, we defined the borderlines of each Greek Administrative Prefecture and Municipality, using **ISO 3166-2**; the script runs in a web-based project created with *Python*.

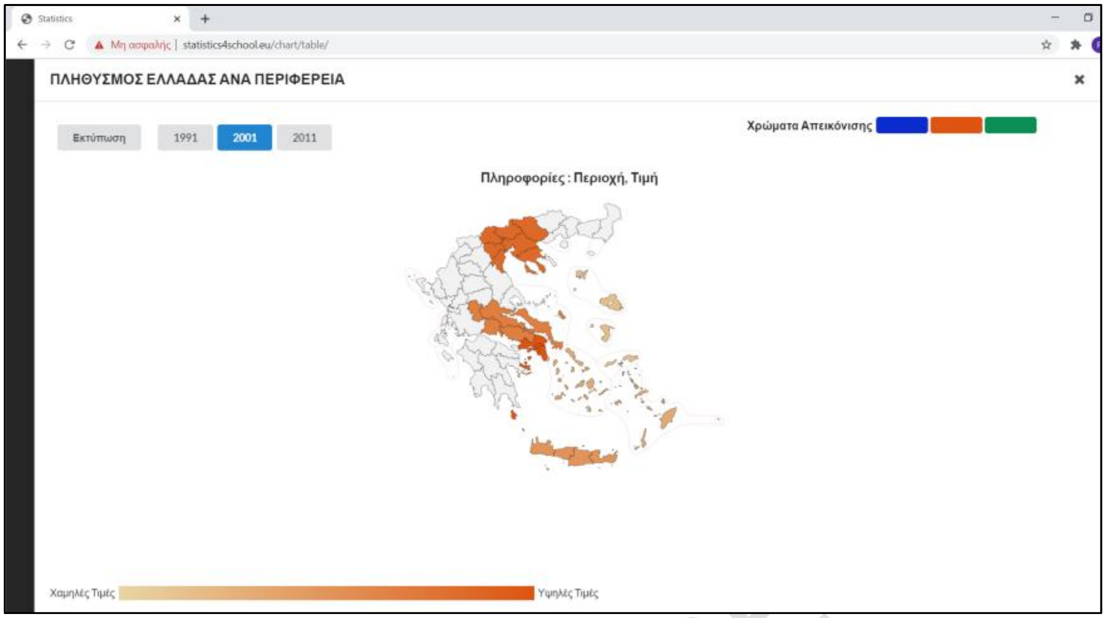

Fig. 6. Visualization with geospatial background of Administrative Prefectures

At the very top of the page, the Title we gave at the initial screen in Figure 3, appears as the header. Below, there are buttons responding to each 'column' (year); we have the option to dynamically switch off data display for any year, by clicking on its button (toggle on/off). At the top right of the window are three available options for the colorization of the areas; the values are hue-related, meaning that the higher the value the darker the hue. One more feature of the map is that when someone hovers their mouse pointer over an area, they get some brief information for it (region name and statistical data value), which can be very useful.

Currently we cannot alter the region for which statistical data are presented – only the year(s). In order to choose different regions we need to close this window (big 'X' at the top right) to go back and make our changes there. Finally, once we are happy with our choices and result, we can print out the entire page (button *'Εκτύπωση'*, top left).

3. DISCUSSION

In this paper we present the web platform *statistics4school.eu*, for the purpose of teaching Statistics in Greek schools. The platform is aimed for use by teachers and students alike, offering them an array of useful visualization tools – as well as some file sharing services. The philosophy behind its usefulness has interdisciplinary teaching, visual literacy and spatial thinking at its core.

Its primary functionality allows for both manual input and uploading of statistical data to be processed and, eventually, visualized in a number of typical and stylized methods. What makes it stand out however, is the option to display statistical information against a set geographical background – namely the Prefectures and Municipalities of Greece. We maintain that the combination of geospatial and temporal data represented in such a fashion and the marriage of Statistics with Geography, through ICT, makes for very interesting teaching sessions, which can influence in a positive way students' effort to comprehend the meaning of statistical data and interpret the results in a certain region and how this can affect local societies.

On one hand, the teacher comes in possession of an amply dynamic tool which, when combined with tried contemporary educational-pedagogical practices such as collaborative learning, interdisciplinarity, guided exploratory learning, can lead to engaging courses and help their students acquire skills, attitudes and behaviors to serve them in their adult life. On the other hand, the students' representation of specific statistical data using a map at the high administrative levels of either Prefecture or Municipality for a selected year span leads to deeper and broader grasp of the magnitude of changes that took place over time, in that area. 'Abstract' mathematical structures – such as standard deviation, average growth, percentage variation etc. - become joined with images to form cognitive objects that would otherwise be rather unassociated for the student.

Initial responses, both from teachers and students, have been quite positive. However, to get a better, broader and more concrete assessment we decided it is imperative to carry out a survey on the matter. Therefore, we composed two different questionnaires – one for each group of the platform's users – and asked them to kindly complete. At present we are in the process of encoding and running statistical metric passes on their replies, aiming to present the results in a future report.

4. CONCLUSION

The tried and true practice of cross-thematic teaching and the increased appeal and transmissibility of ICT-enhanced sessions was our primary drive. Furthermore, the lack of a free-to-use analysis and visualization tool which would make use of the map of Greece as the background for our Geography-X interdisciplinary sessions has led to this implementation. We felt that an application such as the web-based platform presented here (*statistics4school*), can be of great service with its high level management, analysis, interpretation and visualization of statistical data, operating on cartographic backgrounds, particularly in the field of Education. What's more, the (elsewhere, tried and tested) teaching format consisting of e-classes and webinars that was forced upon schools around the world due to the COVID-19 lockdown measures, made associated applications emerge prominently as more than a supplement to education. It is our firm belief that such Web 2.0 & 3.0 platforms are an integral part of the future of Education.

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