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Research Article

Metadata: A pedagogical tool for the teaching of map projections in Elementary School

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Keywords

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Abstract

Digital interactive maps include a set of metadata, which show the purpose the user can use the map. Metadata in digital interactive world maps inform users about important information, such as the map projection. This research examines whether the educational and teaching use of the metadata of digital interactive maps construct a tool in the approach to the issue of map projection in Elementary School. The research was carried out in 17 Elementary Schools of Thessaloniki, Greece, where 6th-grade students (N = 655) were engaged in a series of activities related to metadata and map projections. ArcGIS Online was used as a didactic tool. Results showed that metadata of digital interactive maps have a great pedagogical value. The identification of the different information in the metadata, i.e., the map projection, and the students' decision of what they can and cannot study with each map, is an important finding regarding their educational relevance.

Highlights:

-Metadata of digital interactive maps inform students about important information: the map projection.

-The identification of the different type of map projection, but also the acknowledgment of what students can study with each specific projection is an important finding in terms of the educational importance of metadata.

The publication of the European Journal of Geography (EJG) is based on the European Association of Geographers' goal to make European Geography a worldwide reference and standard. Thus, the scope of the EJG is to publish original and innovative papers that will substantially improve, in a theoretical, conceptual or empirical way the quality of research, learning, teaching and applying geography, as well as in promoting the significance of geography as a discipline. Submissions are encouraged to have a European dimension. The European Journal of Geography is a peer-reviewed open access journal and is published quarterly.

1. INTRODUCTION

Metadata are often defined as data about data. When we hear the word metadata, one may think that is a scientific term related to computer science, to geographic information systems, far removed from our daily life. However, in everyday life we use metadata. Metadata help us use a variety of software or applications or to locate information on the internet. We communicate via email, we upload photos on Facebook or Instagram, we search for a specific video on Youtube. The content of the above activities is accompanied by metadata, i.e., information related to the creation of the element, its name, its subject and its characteristics. The most important reason that makes metadata so valuable is interoperability (Robson, 2001; Zeng & Chan, 2004; Nogueras-Iso et al., 2004; Taylor, 2004; Greenberg, 2005; Register et al., 2009; Gill et al., 2010). In the field of Geography, metadata are an important pedagogical tool (Greco, 2018), which is designed for a particular purpose or to solve a particular problem (Gartner, 2016). Digital interactive maps include a set of metadata, which show the purpose we can use the map. With another words, metadata in digital world maps inform users about important information, such as the type of map projection. Although the value and importance of metadata have been researched in many fields of science (biology, medicine, libraries, computer science), there is a research gap in the field of education. All the researches that have been carried out in the field of education regarding metadata concern their technical part and not their pedagogical value.The present research, having identified the research gap, uses the metadata of digital world maps and "leads" them to the classroom, to sixth grades students of Elementary School, to explore their didactic and pedagogical value.

The subject of map projection is a current and timeless issue and one of the most challenging ones encountered in Geography Education. It is mathematically impossible to transfer correctly the three-dimensional spherical shape of the earth geometrically exactly to a two-dimensional map (Schommer, 2019). A projection is the system by which points on the Earth or globe are assigned to points on a flat surface (Snyder & Voxland, 1989; Olson, 2006). The problem is that every map projection is distorted (Olson, 2006). Distortions on map projections include shape, area, distance and angles. No map projection can preserve all geometric properties (area, distance, direction, angle, shape) at every location when projecting terrestrial features from globe to plane (Basaraner & Cetinkaya, 2019). Students, as map users, need to recognize what is and is not distorted on map projections and need to know what they can and cannot do with them, to be able to use maps better in their school or personal life. The educational and teaching use of the metadata of digital interactive maps construct a tool in the approach to the issue of map projection in Elementary School.

2. BACKGROUND

2.1 Metadata

Metadata are often defined as data about data or information about information (Hodge, 2001; Day, 2001; Agnew, 2003; Nogueras-Iso et al., 2005; Abdillah, 2012). The term "meta" derives from the Greek word denoting a nature of a higher order or more fundamental kind, "meta-" means change and metadata describe the origins of and track the changes to data (Haynes, 2004; Nebert, 2004; Abdillah, 2012). Metadata describe and explain available data (Hodge, 2001; Day, 2001; Agnew, 2003; Haynes, 2004; Nebert, 2004; Nogueras-Iso et al., 2004; Greenberg, 2005; Nogueras-Iso et al., 2005; Danko, 2011; Chuttur, 2011; Abdillah, 2012;), evaluate information and data (Register et. al, 2009; Abdillah, 2012). Moreover, metadata are the key to ensure that resources and data will survive and continue to be accessible into the future (Olfat et al., 2012; Hodge, 2001; Day, 2001; Agnew, 2003; Batcheller, 2008; Cluttur, 2011), organize data (Agnew, 2003), help us locate an information or a data (Olfat et al., 2012; Hodge, 2001; Day, 2001; Agnew, 2003; Schultz et. al, 2008; Register et. al, 2009; Batcheller, 2008; Abdillah, 2012). Metadata provide information to help manage a resource (Hodge, 2001; Day, 2001; Bacheller, 2008; Register et. al, 2009) or to select a resource (Olfat et al., 2012; Agnew, 2003).

While the first use of "metadata" originated in contexts related to digital information (chiefly with regard to databases), the general understanding of the term has since broadened to include any kind of standardized descriptive information about resources, including non-digital ones. So, for example, library catalogues, abstracting and indexing services, archival finding aids and museum documentation might all be seen as containing metadata (Wason & Wiley, 2000; Day, 2001; Agnew, 2003). In addition to "metadata", the terms "spatial metadata" (Smits, 1999; Schultz et. al, 2008), "geography metadata" (Nogueras-Iso et al., 2005) and "geospatial metadata" (Nebert, 2004; Batcheller, 2008; Danko, 2008; 2011) are also found in the literature. In general, the above three types of metadata are metadata about spatial information concerning objects or phenomena that are directly or indirectly associated with a location relative to the Earth; auxiliary information which provides a better understanding and utilization of spatial information (Danko, 2008).

2.2 Map Projections in Education

Map projection is an element which be found in metadata. The lack of knowledge of map projections leads to a number of difficulties in working with maps and often promotes misconceptions about the shape and the size of countries and finally influence our perception of the world (Saarinen et al., 1996; Monmonier, 2004; Wood et al., 2006; Battersby & Montello, 2009; Hong, Luo & Wang, 2015; Basaraner & Cetinkaya, 2019; Schommer, 2019). Map projection is a current and timeless issue. First, developments in the field of map projections occur, for example the deriving of a new map projection (Kessler, 2018). Moreover, in the field of education new didactical approach in map reading is observed, such as Boston Public Schools that announced the switch to the Gall-Peters projection for all classroom maps showing the entire world (Šavrič et al., 2019). At the same time, a number of new applications and videos have recently appeared on the internet that approach the subject of map projections in a remarkable, simple, understandable and playful way[1].

However, despite the timeless and importance of map projections in cartographic education, the number of research outcomes is still limited and there is much left to investigate regarding the map reader and the map projection (Kessler et al., 2017) and the skills and understandings in reading digital maps (Catling, 2018). Unfortunately, many people in the field of education do not have cartographic and geographical knowledge. Few of us think that our standard maps might be woefully inaccurate (Gutstein, 2013) and children 11/12 years old do not know neither what the maps really tell them nor their limitations (Wiegand, 2006). Map projection is one of the most challenging ones encountered in Geography Education (Olson, 2006), but if we teach them effortlessly, through exploration, and active student participation, using educational tools such as the method of comparison (Olson, 2006), then knowledge will come without pressure (Shin, 2006; Klonari & Tzoura, 2011). Primary children have to grapple with the relationship between a globe and a flat map (Catling, 2018).

Some researchers have taught map projections to their students using the method of comparison (Brainerd & Pang, 2001; Hawkins 2003; Ashmore, 2003; Gutstein, 2013, Valovicová et. al, 2019; Schommer, 2019). Schommer (2019) suggests that the use of globes, internet mapping tools and maps with different map projection can prevent the manifestation of misconceptions in Elementary Schools. Moreover, Catling (2018) suggests that children 5-8 years old can compare a globe and world maps and look for the same features on each and children 9-12 years old can compare how parts of the world are shown on globes, wall maps of the world and what is similar and different. Therefore, map projection can be taught in Elementary School via comparative method and using the digital maps′ metadata.

2.3 GIS and Geography

GIS is an effective and powerful tool in teaching Geography because makes the presentation of data more attractive (Attfield et. al, 2002), improves critical spatial thinking (National Research Council, 2006; Walshe, 2017), enhances the interdisciplinary approach (Donaldson, 2001; Bodzin & Anastasio, 2006; Rød et. al, 2010; Baker et al., 2012, Lambrinos & Asiklari, 2014), helps students answer geographical questions (Peterson et. al, 2020), help students ask geospatial questions and search for answers by querying the data (Roberts, 2013; Goldstein & Alibrandi, 2013; Fargher, 2018), leads students to solve real problems (Wiegand, 2001; Johansson, 2003; Baker et al., 2012; Roberts, 2013; Lambrinos & Asiklari, 2014; Jadallah et al., 2017, Walshe, 2017; Roberts, 2017), increases students' global and local spatial understanding by using real-world tools (Bednarz & Van der Schee, 2006) and, finally, is a powerful tool for teaching World Geography (Jo et al., 2016).

3. AIM OF THE RESEARCH AND METHODOLOGY

The aim of this research is to examine whether the educational and in-class use of the metadata construct a tool in the approach to the issue of map projection. For the needs of the research, the research team used digital online interactive world maps addressed to elementary school students.

3.1 Participants

Six hundred and fifty-five students (N = 655) from thirty-eight (38) sixth-grade classes in seventeen (17) Elementary schools in Thessaloniki City, Greece, participated in the present research. The Urban Complex of Thessaloniki was divided into 2 strata: The Directorate of Primary Education of Eastern Thessaloniki and the Directorate of Primary Education of Western Thessaloniki. Then, 10% of schools of each Directorate were selected for the present study. The selection was based on socio-economic similarities among them (degree of urbanity of the schools in more or less undeveloped areas, rate of immigrant students and repatriated immigrants, size of schools; (see Tourtouras, 2010:150-155). Prior to the research, the students' parents signed the necessary consent form to participate in the research. The students answered the questions anonymously.

3.2 Design and Procedure

The design consisted of three main elements: (1) the ArcGIS Online-focused activities designed for this study; (2) classroom implementation; (3) data collection, processing and analysis.

3.2.1 The ArcGIS Online-focused activities

The main software tool used for this study was ArcGIS Online. ArcGIS Online was used, because it is a friendly environment for students.The 3D representation of Earth and three digital world maps in different map projections were used as base maps (Figure 1, Figure 2, Figure 3, and Figure 4). The three map projections presented were Mercator (Figure 2), Robinson (Figure 3) and Peters (Figure 4). The names of map projections were anonymized for the students; therefore, the world maps were assigned with the numbers 1, 2 and 3 for the projections of Mercator, Robinson and Peters, respectively. The geographical regions that students had to study in the above world maps were: Africa, Greenland, Brazil, Spain, Iceland, Mexico and Finland. So, these regions were coloured for better visibility. The metadata of each digital world map included the names of all the colored geographical regions (Africa, Greenland, Brazil, Spain, Iceland, Mexico, Finland), as well as the name of the corresponding map projection (Map 1- Mercator Map Projection, Map 2 – Robinson Map Projection, Map 3- Peters Map Projection) (Figure 5).

Figure 1: The 3D Representation of Earth. Geographical regions that students will study were colored. Due to the shape of the earth not all geographical areas are shown in this image.

Figure 2: Digital World Map 1 - Mercator Map Projection. Colors and signs were added to this world map, so that students could easily observe the size of specific geographical regions.

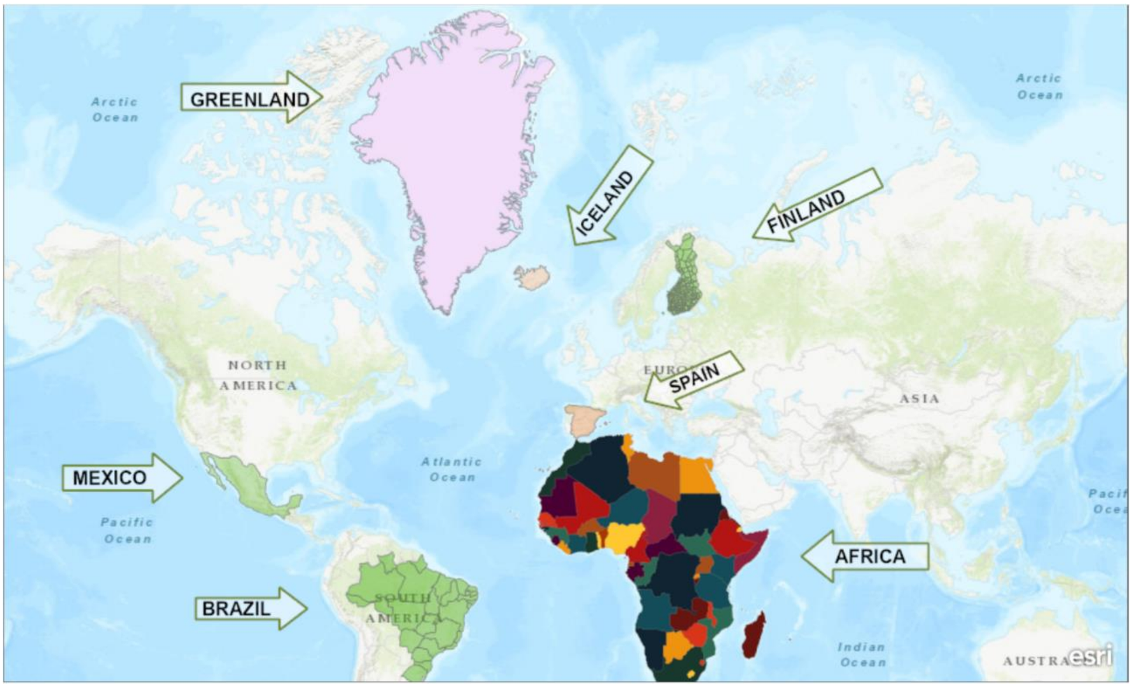


Figure 3: Digital World Map 2 - Robinson Map Projection. Colors and signs were added to this world map, so that students could easily observe the size of specific geographical regions.

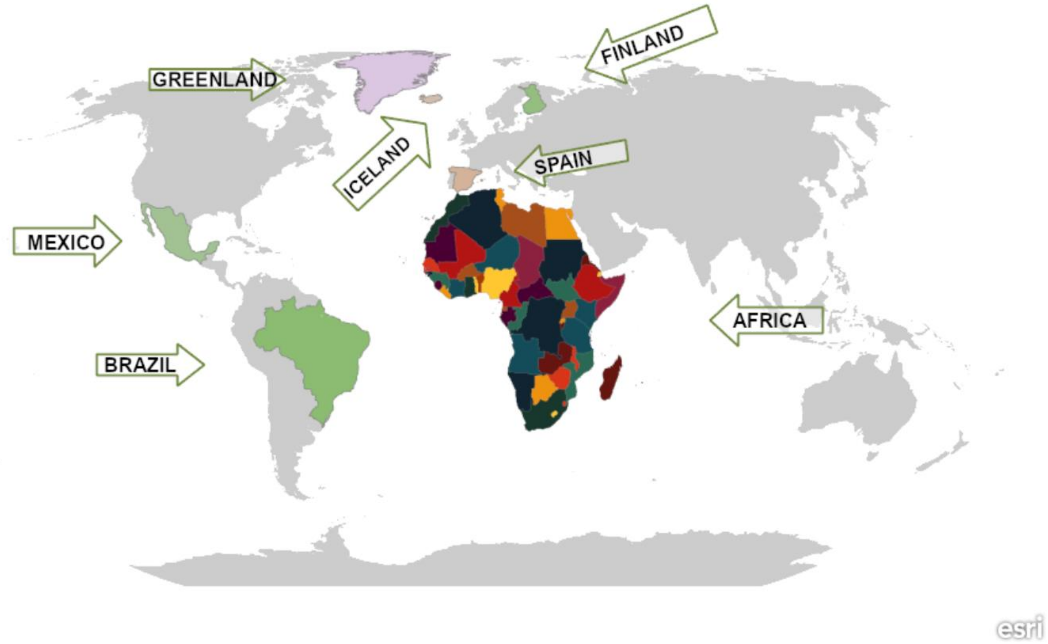
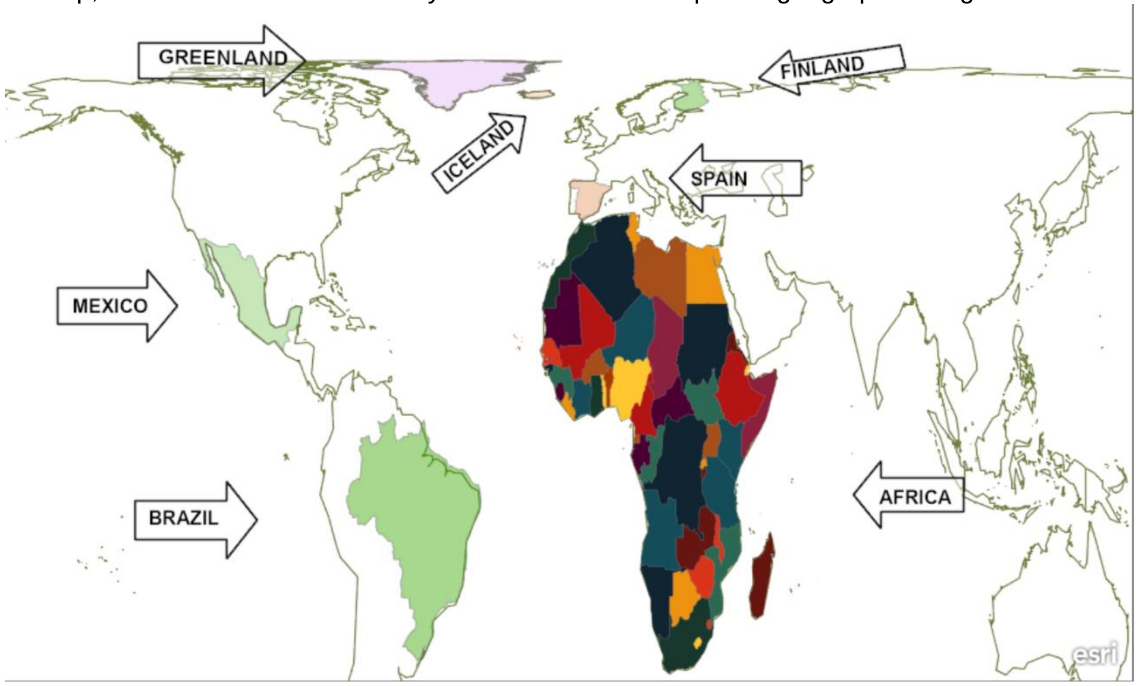


Figure 4: Digital World Map 3 - Peters Map Projection. Colors and signs were added to this world map, so that students could easily observe the size of specific geographical regions.



3.2.2 Classroom implementation

For each of the four world maps (3d, Mercator, Robinson, Peters), students were asked to observe and compare the size of the following geographical pairs: Africa – Greenland, Brazil – Greenland, Spain – Iceland and Mexico – Finland. Then, students were asked to use the website www.thetruesize.com to record the actual size of the above countries and continent. This website includes a digital interactive Mercator map and gives the user the opportunity to move any country to any place on the map, observing its increase or decrease in size, as it moves away or closer to Equator, respectively. Due to the graphical representation and interactive environment, the website can be used in both the Elementary School and in the High School. Students can compare the size of two countries by placing them side by side and also, they can be provided with information of each country, such as its actual area in square kilometers (km^2). After recording the actual area of the geographical regions, students answered the following questions:

Q1. Which of the 4 representations of the Earth (3D, Map 1, Map 2, Map 3) perfectly reflects the actual size of the countries and continent?

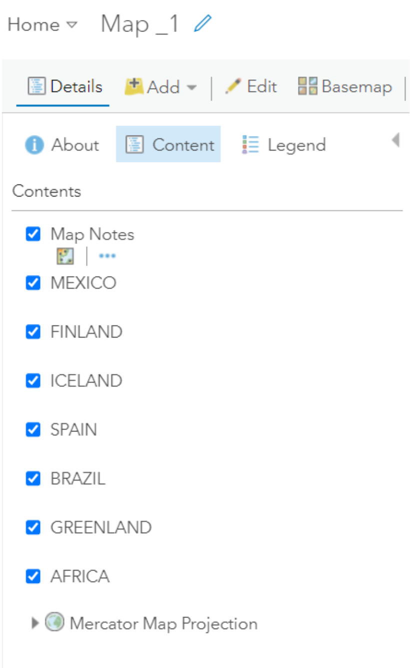
Q2. Which map (Map 1, Map 2, Map 3) would you not suggest to a classmate if he/she wanted to study the size of the countries and continents?

Q3. Which map (Map 1, Map 2, Map 3) would you not suggest to a classmate, if he/she wanted to study the shape of the countries and continents?

Q4. Which map (Map 1, Map 2, Map 3) keeps an appropriate balance between size and shape of countries and continents?

Q5. Take a look at the details of each map. Can you detect what piece of information is different across the maps?

Figure 5: The metadata of Map 1 (Mercator Map Projection) included the names of all the colored geographical regions, as well as the name of the specific map projection. The same information is also included in the other two digital world maps (Robinson Map Projection and Peters Map Projection).



Then, students watched an educational video regarding the problem of projecting the three-dimensional surface of the Earth on a two-dimensional map (https://www.youtube.com/watch?v=kIID5FDi2JQ). Also, it introduces the topic of map projections and what are the different types of maps. Finally, after the video playback had ended, they were asked to answer two questions:
Q6. What can we study with each of the 3 map projections (Map 1, Map 2, Map 3)?

Q7. What basic information should we look for in the metadata of a digital world map?

3.2.3 Data collection, processing and analysis

The data from the students' answers were coded and imported in IBM SPSS Statistics, version 25 (IBM Corp., Armonk, N.Y., USA) where they were statistically processed. The descriptive statistics were presented as frequencies (N) and percentages (%).

3. RESULTS

Table 1 presents the frequencies and percentages of the students' answers regarding question Q1 *("Which map perfectly captures the actual size of each country/continent")*. The majority of students chose correctly the three-dimensional projection of the Earth (*N* = 408, 62.3%), followed by Peters' map projection with 18.6% (*N* = 122) and Robinson projection with 12.7% (*N* = 83).

Table 1. Which map perfectly captures the actual size of each country/continent?

	N	**%**
All of them	5	0.8
Three-dimensional (3D)	408	62.3
Mercator	26	4.0
Robinson	83	12.7
Peters	122	18.6
None	11	1.7
Total	655	100.0

Questions Q2 and Q3 (Table 2) examined the opinions of students regarding projection maps that are not appropriate to capture the size and shape of countries and regions. Regarding the size (question Q2), almost all students (*N* = 634, 96.8%) would not suggest the Mercator projection to a classmate who would like to study the sizes of countries or continents. The other two map projections (Robinson and Peters) shared very low percentages in the answers of students (1.1% and 2.1% respectively). Concerning the shape of countries and regions (question Q3), the majority of students (*N* = 626, 95.6%) would not suggest the Peters projection for the study of the various shapes of geographical regions. The other categories showed noticeably low percentages, as 1.2% (*N* = 8) would not recommend Robinson and 2.6% (*N* = 17) would not recommend Mercator projection. The final question (question Q4) of this part showed that most students chose the Robinson map projection (*N* = 630, 96.2%), as the best world map that keeps a good balance between size accuracy and shape of region. On the other hand, only the 1.4% (*N* = 9) answered that Mercator maintains balance and 2.4% (*N* = 16) indicate that Peters maintains a balance.

Table 2. Frequencies and percentages of opinions about size, shape and balance

	Mercator	**Robinson**	**Peters**	**All of them**
Questions	***N* (%)**	***N* (%)**	***N* (%)**	***N* (%)**
Q2	634 (96.8%)	7 (1.1%)	14 (2.1%)	-
Q3	17 (2.6%)	8 (1.2%)	626 (95.6%)	4 (0.6%)
Q4	9 (1.4%)	630 (96.2%)	16 (2.4%)	-

Q2: Which map would you not suggest to a classmate if he wanted to study the size of countries or continents.
Q3: Which map would you not suggest to a classmate if he wanted to study the shape of countries or continents.
Q4: Which world map maintains a balance between accurate size and shape of regions?

For the next part, students were asked to search in the metadata of the three digital world maps (Figure 5) and find the information that differs from the others i.e the specified type of map projection. The majority of students (Table 3) successfully navigated in the appropriate menu of metadata and identified that the map projection is different between the three digital world maps. More specifically, regarding the Mercator projection, 90.2% of the students (*N* = 591) correctly located the type of map projection, while for the Robinson and Peters projections the percentages were 89.8% and 89.6%, respectively. The rest of the students either didn't find the appropriate information or they said that the information had no differences among the maps.

Table 3. Frequencies of the correct identification of metadata

	Correctly identified	
	N	***%***
Metadata Mercator projection map	591	90.2%
Metadata Robinson projection map	588	89.8%
Metadata Peters projection map	587	89.6%

Table 4 presents the answers regarding the question "*What can we study and what not with each of the 3 maps?"* The largest percentage of students stated that the Mercator projection correctly shows the direction of the countries and continents (*N* = 562, 85.8%), while the Robinson map correctly shows both the size and shape of the geographical regions (*N* = 573, 87.5%) and the Peters projection correctly shows the size of the areas (*N* = 540, 82.4%).

Table 4. Frequencies (%) of the projections' identified characteristics

	All characteristics	**Direction**	**Size**	**Shape**
Mercator	3 (0.5%)	562 (85.8%)	39 (6.0%)	51 (7.8%)
Robinson	573 (87.5%)	9 (1.4%)	35 (5.3%)	38 (5.8%)
Peters	14 (2.1%)	8 (1.2%)	540 (82.4%)	93 (14.2%)

Finally, regarding the last question *"What basic information should we look for when studying a world map on the internet*", the majority of students highlighted that the type of map projection is a basic information that we should aim to know for the digital world map we study (*N* = 588, 89.8%). On the other hand, a few students mentioned the date of construction of the map (*N* = 26, 4.0%) or the title of the map (*N* = 41, 6.3%).

5. CONCLUSIONS

The purpose of this study was to investigate whether the metadata of digital world maps could be used as an educational tool in Elementary School for teaching the issue of map projections. The experiment was settled with an ArcGIS Online interactive activity and a classroom implementation. Students used the ArcGIS Online and tried to identify differences and similarities in the shape and size of specific geographical regions illustrated by four different Earth projections, namely the 3-dimensional, Mercator, Robinson and Peters map projections. Also, students were encouraged to find the metadata of each projection and detect the actual type of the map that they observe. Afterwards, they visited a website, where they had the ability to compare the actual size of the regions that they had previously observed. Then, students watched an educational video that presented the challenges cartographers face when they aim to project a three-dimensional region into two dimensions. After completing each step, students were asked to answer questions concerning their beliefs about map projections.

In the ArcGIS Online setting, the majority of students identified in the metadata the type of map projection in all the three world maps. Furthermore, after watching the relevant educational video, they were asked to decide what "is allowed" to study with each map projection. Most of the students correctly stated that the Mercator projection map is appropriate for studying the direction, the Robinson projection map for studying both the size and the shape of the various geographical regions and Peters cartographic map for studying the size of regions. Finally, it was evident that students understood the valuable information provided by the metadata, and they stated that the map projection is something that they should look for every time they study a digital map.

The identification of the different information in the metadata of the digital world maps, i.e., the type of map projection, but also the acknowledgment of what they can study with each specific projection is an important finding, in terms of the educational importance of the metadata. Metadata, which were previously not available in the printed versions of school wall maps, allows the students to access useful information of the type of the map, therefore, they may have great educational and didactic value. According to the present study, when students search for and use them, they can extract important information about each digital world map, such as the map projection, and thus realize what they are allowed to study with each map. This is especially important for sixth graders, who use world maps in different subjects but especially in Geography.

From the above and based on the relevant literature, the view of Greco (2018) stating that in the field of Geography metadata is an important pedagogical tool was confirmed and our results are in line with Gartner (2016), proposing that the metadata serves a specific purpose or solves a specific problem. They are necessary in geographic information systems (GIS) for the efficient use of spatial data, as they inform users about the cartographic projection and help them assess whether the projection observed is appropriate for their needs (Bolstad, 2016).

Regarding the map projections and their distortions, it is important to find that the students, through their research, found that the various world maps do not present the earth's surface in the same way. Previous studies suggested that comparing world maps is the right way to introduce the concept of cartographic projections into the classroom (Lambrinos, 2009). In our case, most students detected this variability and stated the Mercator map as inappropriate to study the size of geographical regions and the Peters map as inappropriate to study the shapes, while at the same time confirming that the Robinson map keeps a balance in the way it projects the size, area and shape of the regions. Concluding, they found that the absolutely correct mapping of the Earth's surface, without any distortion, is the 3d representation of the Earth.

Metadata as educational and didactic tool has been examined in terms of approaching the subject of map projections in the classroom. Because we refer to information technology resources that are spatially related to the Earth, the term "Spatial Metadata" (Smits, 1999; Schultz et al., 2008), "Geographical Metadata" (Nogueras-Iso et al., 2005) and "Geospatial Metadata" can also be used (Nebert, 2004; Batcheller, 2008; Danko, 2008; 2011). Thus, spatial, geographical or geospatial metadata could act as a highly important pedagogical tool during the teaching process of map projections in Primary Education. The user of a map, whether he/she is a teacher or a student/trainee should know the map projection of each digital map he/she will use, in order to know what are the special characteristics of the map projection.

However, the relevant literature has highlighted a problem, as many educators have a lack of knowledge regarding cartographic and geographical education (Tzotzis, 2007). Many teachers commonly have vague perceptions about the object of cartographic projections and do not know that all two-dimensional maps have inaccuracies (Gutstein, 2013). Thirty-four years ago, Snyder (1987) stated that "Working with map projections still strikes fear in the hearts of many trained cartographers and geographers." At the same time, during the implementation of the present research in Elementary Schools, many teachers stated that they were not aware of the subject of map projections, but they would like to learn more about it. Therefore, the issue of map projections should be more relevant to the educational community, so that it can then be implemented in the classroom environment by the teachers.

Apart from Geography, engaging in map projections is an activity that cultivates students' spatial thinking, since map projections are part of the complex concepts that cultivate spatial thinking (Golledge, 2002; Scholz et al., 2014). More specifically, students cultivate their spatial thinking, as they come into contact with complex spatial concept, map projections, through activities that lead them to a high level of reasoning and justification, as they are asked to compare, contrast and categorize different map projections. Moreover, metadata and map projection awareness develop the critical thinking skills and the visual literacy skills in young students. Working on cartographic representation helps to show students that the map is constructed and therefore not neutral and objective. This is one of the challenges of education today: learning to read images critically. It is necessary, to incorporate techniques to teach young students how to evaluate images.

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