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Research Article

Web GIS to Learn Geopolitics in Secondary Education: A case study from Spain

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Abstract: Teachers' increasing use of cloud-based Geographical Information Systems (Web GIS) in an interactive way in Spanish secondary schools highlights the importance of researching the effectiveness of this new approach. This study employs action research qualitative methods, through direct teacher observation, and quantitative methods to analyze student grades following first use of Web GIS. Specifically, the research involved: a) Design: organizing a geopolitics' lesson plan, with seven tasks, for a sample comprising 92 students at K10 level (15-16 years old); b) Comparison: contrasting the results of a traditional written exam following the use of two technologies (namely, Web GIS and a conventional PowerPoint presentation); c) Data collection: analyzing quantitative data via a descriptive and inference study of grades (involving a geopolitics exam; geography and history final term; Grade Point Average -GPA-; and the average grade of the entire term's 10 curriculum subjects); d) Direct observation: assessing class interactions in which students are assisted with both technology (Web GIS or PowerPoint) and the clarification of concepts. The results demonstrate that Web GIS is a useful learning tool in geopolitics, with students getting better grades and no significant gender differences. Direct observation confirms how Web GIS technologies engage students; assist 'ubiquitous learning' from any place and at any time; improve their understanding of data analysis and spatial concepts; and enhanced digital competencies.

Keywords: secondary education; geography; competencies; history; Web GIS; geospatial technologies; education assessment.

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Highlights:

- Web GIS engage students in learning geopolitics and enable them to obtain better grades.
- Students improve their understanding of spatial concepts using Web GIS.
- Web GIS in secondary school improve data analysis, spatial and digital competencies.

1. Introduction

Maps are an effective means of enhancing teaching and learning and a powerful tool for presenting research findings. Graphics and maps have a recognised pedagogical value, even if they are historical maps (Parellada, 2017). Cloud-based GIS - or Web GIS –Web 2.0, Global Navigation Satellite Systems (GNSS) and other technologies are all driving the increased use of this new approach. Web maps can present data in any format on maps, whether through statistics (via all types of graphics), multimedia elements (podcasts and videos) and/or images such as photographs, in an increasingly user-friendly way (Buzo-Sánchez et al., 2022). Using these tools, it is possible to create different applications or viewers, such as web maps or web applications. A new approach to territorial analysis can be undertaken on Web GIS and digital interactive maps using key components such as open software, open data, open standards, and open education. Thus, visible information and geographical data accelerate the process of filtering and managing data and their meanings. Visualization enhances learning (Fekete et al., 2008; Bondarenko, 2019).

GIS and of course Web GIS are useful in improving data management and developing critical spatial thinking (Bearman et al., 2016). In this context, the National Research Council (2006), cited by Kim and Bednarz (2013, p. 351), states the need for users to: "(1) assess the quality of spatial data such as accuracy and reliability based on their source, (2) use a spatial rationale as a way of thinking to construct, articulate, and defend a line of reasoning in solving problems and answering questions, and (3) evaluate the validity of arguments or explanations based on spatial information".

Thus, Web GIS are now used in most areas of research, teaching and knowledge dissemination, for example, in geography (Giannakou & Klonari, 2019; Mukherjee, 2019), heritage (Martínez-Hérnandez et al., 2022), tourism (Mínguez, 2021; Mínguez et al., 2021), urban and regional planning (Santos et al. 2021), archaeology (Klingman, 2021; Pons et al., 2019); health issues (Wilson et al., 2021); and fieldtrips (Leininger-Frézal & Sprenger, 2022). Web GIS has been employed in secondary education since the 2010s (Milson, 2011) and authors such as Buzo-Sánchez et al. (2022) and Fargher (2018, 2019) have found evidence of their efficiency in the teaching and learning process. However, research into the use of Web GIS in education is still rare, fragmented, uneven, and slow (Baker et al., 2015; Jackson & Kibetu, 2019; Kerski et al., 2013; Schulze, 2021).

There are many barriers to implementing Web GIS in secondary lessons because it requires: pedagogical resources (Puertas-Aguilar et al., 2022); management and technological skills (Buzo et al., 2022); clear inclusion in the curriculum (Bednarz & Van der Schee 2006), and additional teacher training (Puertas-Aguilar et al., 2021). Furthermore, the pedagogical tools necessary to enable new teachers to integrate rapidly evolving cloud computing GIS technology into classrooms (Mitchell et al., 2018) require the implementation of GIS-based methods that frequently overload

teachers. Teachers in training should be aware of the importance of web-based services in daily economic and social activities and speed up the introduction of Web GIS in the classroom helped by instructors or teachers' trainers. The innovative pedagogical change needed in teacher education, should integrate blended learning and training (Puertas-Aguilar et al., 2022; Zwartjes & De Lázaro, 2019). Thus, teachers will be helped to understand both the implementation process and the underlying science, by developing basic GIS skills and competencies. The current Spanish national curriculum is focused on competencies, derived from EU recommendations (2018): "competences are defined as a combination of knowledge, skills and attitudes, where: knowledge is composed of the facts and figures, concepts, ideas and theories which are already established and support the understanding of a certain area or subject; skills are defined as the ability and capacity to carry out processes and use the existing knowledge to achieve results; attitudes describe the disposition and mind-sets to act or react to ideas, persons or situations". The document defines eight blocks of competences, most of which are of relevance to this research, which predominantly focuses on skills in spatial critical thinking, that is specific to geographical science, literacy, and digital competences.

Other barriers to introducing Web GIS include: the pace of technological change; schools' computer speeds and capacity; shortages of resources and lesson time; the lack of links to curriculum and standards; and the lack of administrative and technical support. This means that both a structure and management are necessary to engage students in technology and develop better and more flexible learning solutions, in a process that might be described as a methodological revolution. In fact, the question has now shifted from whether technology has a place in the classroom to how technology can be integrated into the curriculum and especially into teacher training (Curtis, 2019; DigComp, 2016; Höhnle et al., 2016; Vuorikari et al., 2022). The Coronavirus pandemic has accelerated this process and has given a boost to hybrid teaching, increasing blended learning (Leininger-Frézal et al., 2023; Bruggerman et al., 2021), flexibility and individualization (Müller & Mildenberger, 2021). All are technically supported by virtual campus, mobile internet, Bring Your Own Device (BYOD), learning management systems, online instruction, computer laboratories, electronic portfolios, and e-mail (Dziuban et al., 2018).

This research reinforces the idea that Web-based GIS is a very practical, active, and relevant way of incorporating digital technology into secondary school education even if it has never been done before. Geopolitics has been chosen because there is no significant research that demonstrates an improvement in student grades in arts and geopolitics' exams as the result of the use of web mapping. Additionally, (i) it is a key element in the K10 geography Spanish compulsory secondary education curriculum (around 15 % of the official topics are related to it); (ii) it is considered knowledge that 15 year old students should have to understand today's global world, particularly when they apply to university or for a job abroad; (iii) visualizing spatial arrangements and patterns using geographic representations on a Web GIS make it possible to acquire or strengthen spatial competence.

Thus, the main objective of this research is to determine how Web GIS first engages students to study and learn about geopolitics. This will be assessed by traditional written exam grades because they seem more objective than results from other learning activities or lesson tasks. All students do the written exam under the same conditions (same time, same place, and same question types).

This study analyzes whether assessment employing a traditional exam produces different results for students using, versus not using, Web GIS. To meet this aim, Web GIS must be integrated in a natural way in daily lessons. A second objective is to check whether there are any differences by sex in secondary education learning results (Rizou et al., 2022).

2. Materials and Methods

Action research has been chosen as the best method to respond to these questions. The analytical framework can be expressed in a circle (Figure 1). Further explanation about the comparison method based on grade results can be found in Simon and Budke (2023) (Table 1), which is based on a sample using, and not using, Web GIS. For the final grades, a variety of activities have been considered (Appendix A).

The case study is a geopolitics lesson for K10 students, consisting of the last of 14 lessons in the geography and history curriculum. The highlights present world reality to improve students understanding about the facts and events that have led to it. In practice, a review of the previous two centuries that links causes and consequences can provide a vision of today's world and geopolitical issues. The geopolitical lesson pertains to the discipline of geography and history, taught together on the Spanish curriculum, which incorporate contemporary history beginning with the French Revolution and ending with a lesson called 'The world today'. Students in the term also study other lessons that cover general western contemporary history from the Cold War to September 11, 2001.

A blended learning experience was developed during the 2020 pandemic. Students had to take presential lessons in rotation (i.e., not all at the same time). Each student was provided with a personal iPad to facilitate digital activities.

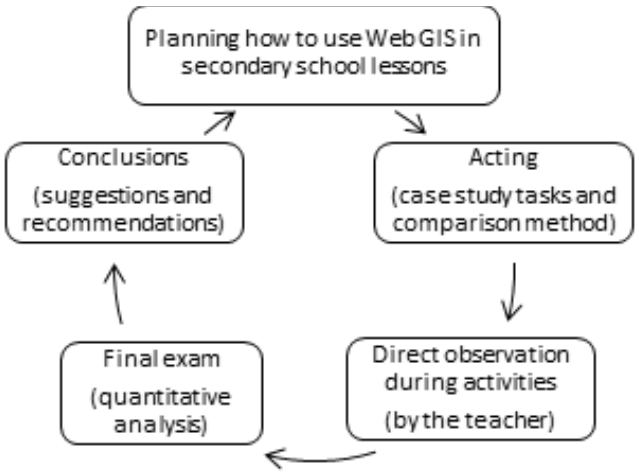

Figure 1. Action research method used. Own creation.

Table 1. Comparison method used according to Simon & Budke (2023).

Steps	Indicator
Determine comparison units	Students in groups (A, B and C) and term grades (geopolitics[1] case study, geography and history[2], and GPA[3]).
Determine comparison variables	Those who use Web GIS and those who do not. Gender.
Juxtapose comparison units with variables	Term grades (GPA, geography and history, and geopolitics) in class groups by sex; using Web GIS and not.
Weight variables and explain results	The weight of each variable is the same.
Formulate an answer to the question	Question: assessment using a traditional exam will produce different learning results for students using, and not using, Web GIS.

[1] *Geopolitics lesson exam*

[2] *Geography and history final term grades. Includes two written exams per term, participation in debates, oral presentations, exercises (including those to help students identify disinformation and fake news), and written essays using different procedures: images, texts, and maps analysis).*

[3] *Grade Point Average (GPA). The average grade of the entire term's 10 curriculum subjects. This category provides a background of the different groups' academic levels.*

2.1. Participants' organization

Three different groups participated in the research. They were organized, as usual, by school managers (researchers didn't participate) at the beginning of the school year, attending to these criteria: no group should have more than 33 students, students must socially fit together based on compatibility and ability to work collaboratively (they must have some friends in the group, and no students with 'unresolved problems' in recent years should be in the same class), and the academic level between groups should be similar (with both high- and low-achieving students).. These groups were labelled alphabetically: group A, B and C (Table 2). The teams comprised 4-5 students, organized by researchers, according to school policy which adopted cooperative learning (Johnson & Johnson 1986, 1999) as its basic methodology some years ago. These teams consist of students of different levels of academic achievement (e.g., one good student, one or two regular students and one weaker student). Previous years' grades were used by the school to select members of the cooperative teams (this is not relevant to the study's results, but it describes the actual situation in the classroom and the value of Web GIS for cooperative learning). The 92 research participants had no previous experience of using GIS or Web GIS, and they followed the same curriculum. Group A is more balanced in sex, (a similar number of males and females) so it was chosen to *not* use Web GIS; while groups B and C did. All groups had the same teacher for the action-research case study, who was the same as that for geography and history. This made it possible to do a comparison of students' final exam grades between those who used and didn't use Web GIS.

Table 2. Participant groups and cooperative teams' organization.

Class groups	N	Male	Female	No. Teams[1]
Group A (using a PowerPoint presentation)	28	16	12	7
Group B (using Web GIS)	31	26	5	8
Group C (using Web GIS)	33	22	11	8
Total	92	64	28	23

[1] *Number of cooperative teams within each class.*

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2.2. Students' tasks during the case study

The lesson plan introduced fact or data finding tasks to achieve the research results. These included (Table 3):

- **Task 1.** Presentation: geopolitics concept, globalization concept and supranational institutions (2 sessions). The teacher provides an overview of: (i) the context - including supranational organizations such as the United Nations (UN), the European Union (EU) and the North Atlantic Treaty Organization (NATO), as well as Spanish and global non-governmental organizations (NGOs) such as Amnesty International, The Red Cross, and Greenpeace, among others; and (ii) the geopolitical areas of study across eight different regions: North America; Central and South America; the EU; Africa; post-Soviet countries; the Middle East; Asia-Pacific; and Asia-Indic (including Asiatic countries from Pakistan to Burma and Indonesia).
- **Task 2.** Research and Content Report (3 sessions). Students are required to investigate each of these cited regions, within their previously created cooperative teams. Afterwards, they must write a report. This research is usually quite difficult as it has no model or orientation (scaffolding). The teacher creates a model as a brief guide to help students focus on the topic using three categories: (a) external problems, (b) internal political problems and (c) a general economic overview, involving a summary of about 400/500 words. In detail:

  a) External problems. Identify the main problems that affect the assigned geopolitical area in contrast to other countries/areas. It is important to focus on the largest countries' principal conflicts; the specific degree of influence that a particular country may have on its regional economy; and/or the economic activities that impact on the regional/global economy.
  b) Internal political problems. These relate to problems that may cause internal disruption. Selecting the most critical issues may not be easy; problems must be relevant.
  c) A general economic overview or highlights. The economic and political situation of leading countries because of the specific impact that they may have on the regional economy. Specific economic indicators visualized by a wide number of sources, using maps and graphs provided by the teacher, will help with the task, such as: Gross Domestic Product (GDP) (as it helps to show global impact); GDP per capita (this illustrates every country's relative importance, as it considers the number of inhabitants); GINI index (a measure of inequality); the Human Development Index (HDI), as 'development' is more than GDP data; economic data, identifying the main products and services produced, and raw materials. Notice that we must deal with these indicators in a global way, which will emphasize the leading countries or 'big activities' due to their influence.

  Students' research was assisted by a rubric that is usually considered for the final evaluation. These rubric indicators show the level of achievement on the following competencies: number 1 indicates the worst level; number 4 the best.

  Critical thinking
  1. Student cannot reflect on the topic.
  2. Student repeats simple 'popular messages' without any reflection.
  3. Student presents their own ideas linked to a particular topic.
  4. Student reflects on the topic developing her/his own ideas.

  Social commitment
  1. Unaware about social issues in her/his community.
  2. Demonstrates superficial knowledge about social issues but not much interest.
  3. Can identify what social problems are likely to be relevant.
  4. Clearly knows what social problems are important and offers solutions to them.

  General political knowledge
  1. Student has little idea about politics.
  2. They have some political knowledge, but it is fragmented.
  3. Student has a general idea about politics concerning the topic she/he is most involved in.
  4. Student shows well-developed knowledge about internal and external politics.

  Analytical capability
  1. Student cannot analyze.
  2. Student can mention ideas related to a particular topic but cannot make a proper analysis.
  3. Student can analyze the topic in a superficial way.
  4. Student can make an accurate analysis of the topic.

  Leadership
  1. Waits for instructions from the other members of the group. Does not contribute with any initiative and can be disconnected and apathetic.
  2. Gives their opinion only if asked. Her/his contributions are rare.
  3. Has initiative when developing tasks, but rarely accepts other ideas.
  4. Constant initiative. She/he is capable of reasoning without imposing their criteria on others.

  These competencies are assessed, as well as procedural skills and knowledge required by the Spanish curriculum. During the information-gathering and research process, the teacher seeks to promptly address all students' questions in class. The teacher never directly corrects the work of a particular group, as it is important to wait for students' own reflections. Teachers may use questioning

to promote inquiry-based learning if they are stuck. However, teachers will fully respond to all technical questions relating to the use of Web GIS.

Finally, students gather data and hand in their reports to the teacher. Up to this point, all students have used the same procedures.

- **Task 3.** Learning about the tool (two sessions in the case of ArcGIS Online, and one for PowerPoint as they have used the tool previously. The next stage involves teachers introducing students to the technological tools needed to present the task 2 results. As said, PowerPoint presentations were used by group A, while ArcGIS Online Web GIS were employed by groups B and C. Using different tools to present their results is the only difference in the learning process. Additional tutorial videos help guarantee that all students have sufficient technical knowledge to develop their own activity.
- **Task 4.** Groups B and C develop 'layers', which enable the displaying, querying, and editing of data on the web using a collaborative digital map in Web GIS, known as ESRI's ArcGIS Online (AGOL). ESRI is an American software company that provides schools with free access to the platform upon request. Teachers need some previous experience to successfully implement the software within the classroom. This technology has a simple and attractive interface (Strachan & Mitchell, 2014) and is versatile and multifunctional (Caquard & Dimitrovas, 2017). This first experience in adding data to the map involves the following steps: (i) students start with a survey created by teachers in Survey123, one of the complementary tools of AGOL; (ii) each team sends their work of the specific geopolitical region studied in task 2 in response to the survey, and can see the correct location of the point in the specific region; (iii) students create their own web mapping application very easily using the layers created by Survey123. (Figure 2). As a result, a collaborative digital map is produced online, which students can access at any time, from any place – to, for example, change the icons and pop-ups - to complete their study of the geopolitical content. Therefore, students have their first experience using Web GIS in a basic way. Throughout the school year, the teacher gradually adds more activities, which facilitate the integration of Web GIS into the curriculum. These activities become increasingly complex and difficult using other ArcGIS Online tools, like StoryMaps. Group A makes presentations from geopolitical regional reports (task 2), using PowerPoint or key notes, and afterwards students upload them to a shared folder in the cloud (in this case, Google Drive) so that they are available to study for their exam. Thus, all groups have contributed content for the exam on their own digital maps (groups B and C), or on their shared Google Drive folder (group A) (1 session).

Table 3. Schedule of the case study.

Tasks	No. of sessions	Using Web GIS (Groups B and C)	Using a PowerPoint presentation (Group A)	Teacher' scaffolding
1	2	Presentation. Geopolitics concept. Globalization concept. Supranational institutions.		Teacher overview
2	3	(a) Research; (b) Gathering data for their report.		Guide model provided. Rubrics and explanations. Teacher asks questions.
3	2/1	Introduction to ESRI ArcGIS Online Web GIS (AGOL) and Survey123 tool	PowerPoint overview	Teacher explanation
4	1	Introducing and uploading reports information to ArcGIS Online (AGOL) by using Survey 123.	Create PowerPoint presentations	Teacher helps students on technical, organizational, and content problems.
5	2	Peer evaluation		Rubric explanation. Teacher's assistance.
6	1	Final corrected information on the AGOL map layers.	Final corrections of the PowerPoint information on Google Drive.	Teacher helps students to improve the content and avoid misinformation.
7	1	The same written exam		Teacher exam correction

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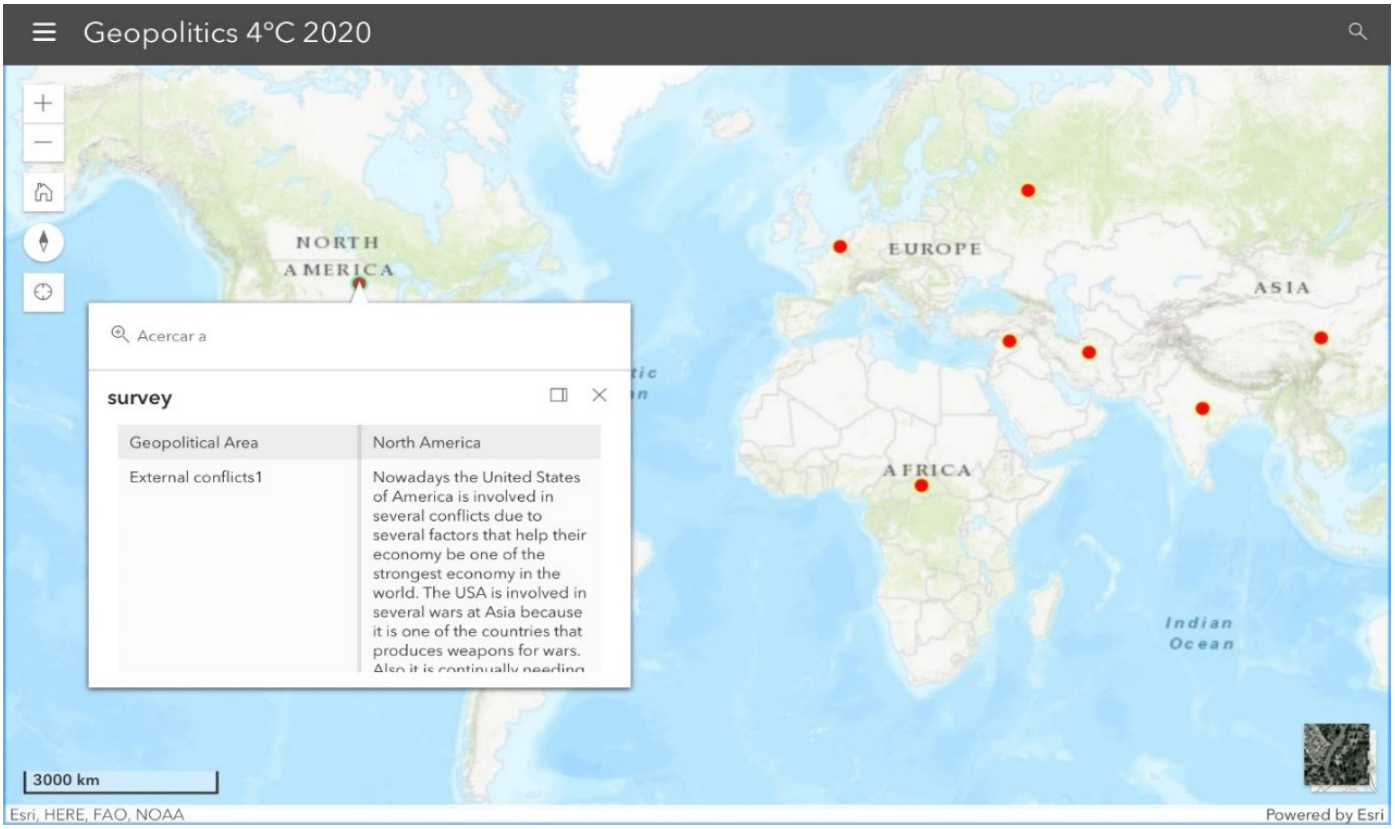

Figure 2. An example of a mapping application or web mapping created on ArcGIS Online. Source: One student team.

- **Task 5.** Peer evaluation (2 sessions). Students must assess their classmates' content within the layers (groups B and C), or presentations (group A). For this purpose, they use another rubric for clarity and to collect relevant information. This peer assessment method helps teachers to give feedback to their students and make them able to prepare learning content for a better writing exam. Again, number 1 indicates the worst level and number 4 the best.

  Clarity
  1. Information is not clear at all. Ideas are mixed and it is very difficult to understand them. There is an evident lack of information.
  2. Information is overwhelming. Too much information without proper explanation. Excessive data that make it very difficult to draw conclusions.
  3. Ideas are well illustrated. Some topics are well developed; others display a lack of or excessive information.
  4. Ideas are well displayed and explained with appropriate information.

  Information relevance
  1. Information given has nothing to do with the topic.
  2. Information refers to minor or irrelevant aspects of the topic.
  3. Information provides a framework of major issues/countries related to the topic.
  4. Information collects all relevant issues in order of importance.

- **Task 6.** Final corrected information (1 session). After reviewing their classmate's work, students must highlight any item they found to be mistaken, irrelevant, or superfluous in their peer's works. Subsequently, those students correct their reports from their AGOL layers, or on their presentations. During this process, teachers help by asking questions to encourage students to reach their own conclusions and improve their final report on the topic. In addition, students should learn to accept criticisms in a mature and natural way, as a part of collaborative learning. The results are reviewed and corrected under teachers' supervision.
- **Task 7.** Finally, students are required to take a traditional written exam about geopolitics (1 session). They must study using AGOL's digital layers created by them and their classmates (groups B and C) or the PowerPoint presentations (group A). Two questions are asked at random in the written exam about the tasks uploaded by students, which were related to the three sections of each geopolitical region (external or internal political problems and general economic overview). The results of the exam will highlight which tool is more successful: a traditional presentation using PowerPoint or ArcGIS Online work.

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2.3. Quantitative method

The lesson tasks are reinforced via a descriptive and inference study for the data set, using grade results. To apply the hypotheses' tests for differences in means, we must first check whether the hypotheses of data normality are fulfilled, since a limited amount of data means that the central limit theorem cannot be applied to use parametric tests. The hypotheses of data normality have been verified for all scenarios by means of the Shapiro Wilk normal test. The data are from normal distributions, which is why we apply parametric tests for all scenarios for independent samples using the T-test for independent samples. For multiple comparisons we apply analysis of variance techniques.

Student grades are presented in three categories: (i) the geopolitics' exam grades itself (hereinafter referred to as the 'Geopolitics exam'); (ii) geography and history final term grades (hereinafter referred to as the 'geography and history term') and (iii) overall term grades for the 10 curriculum subjects, known as the 'Grade Point Average' (hereinafter referred to as the 'Term GPA'). The Spanish system grades students from 0 to 10, which comprises exam results, procedure, and continuous assessment of competency. Thus, the geopolitics exam also forms part of the final student results.

3. Results

Hypothesis tests have been carried out for independent samples to verify at 5% significance level whether there are significant differences in the means of the three marks obtained according to the use of Web GIS or not. The results indicate, using the p-value method, that there are no differences at 5%, however, at 10% there are differences in the mean of the geopolitics exam grades (Appendix B. Contrasts tests results). Table 4 shows the descriptive summaries of the scores; separated by use of Web GIS. Figure 3 shows the variability of the marks/ grades and the median value.

Table 4. Descriptive summaries of grades for all students (as stated, Group A did not use Web GIS (0), while Groups B and C did (1)).

Concepts of grades	**Web GIS use**	**N**	**Mean[4]**	**Sd**
Geopolitics lesson exam[1]	0	29	5.052	2.3579
	1	65	6.062	2.3659
Geography and history final term grade[2]	0	29	6.138	1.5974
	1	65	6.446	1.6108
Term GPA[3]	0	29	7.103	1.5717
	1	65	7.185	1.4776

[1] *Geopolitics lesson exam*

[2] *Geography and history final term grades. Includes two written exams per term, participation in debates, oral presentations, exercises (including those to help students identify disinformation and fake news), and written essays using different procedures: images, texts, and maps analysis).*

[3] *Grade Point Average (GPA). The average grade of the entire term's 10 curriculum subjects. This category provides a background of the different groups' academic levels.*

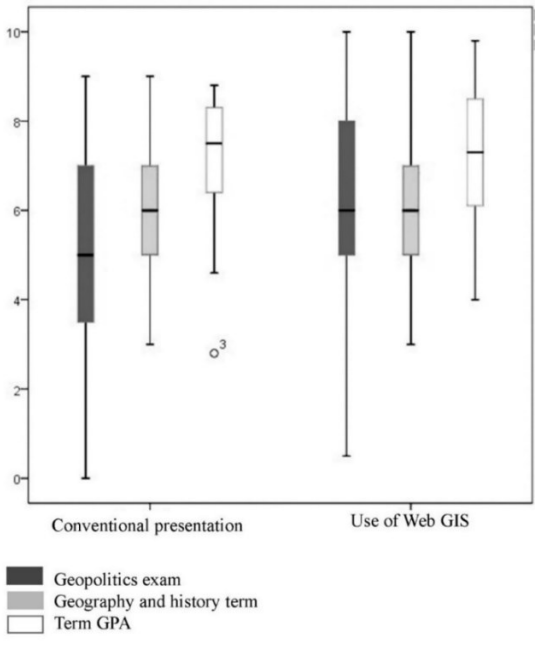

Figure 3. Boxplot of grades (0 to 10) through using, and not using, Web GIS for learning.

3.1. Groups comparison

The analysis of grades results by each group, based on the three previous categories of marks was shown (Table 5). Thus, we can see how the results of the geopolitics exam are better in group C (who had used Web GIS) than in the other two groups, with the last being Group A. Group A had the second-best scores in the geography and history term and in GPA, and Group B was in last place on those two grades (see Figure 4).

Table 5. Descriptors of the grades by groups

Concepts of grades	Groups	N	Mean[1]	Sd	Minimum	Maximum
Geopolitics lesson exam	A	29	5.052	2.3579	.0	9.0
	B	32	5.609	2.5676	.5	10.0
	C	33	6.500	2.0991	1.0	10.0
	Total	94	5.750	2.3971	.0	10.0
Geography and history final term grade	A	29	6.138	1.5974	3.0	9.0
	B	32	5.875	1.4536	3.0	9.0
	C	33	7.000	1.5811	4.0	10.0
	Total	94	6.351	1.6045	3.0	10.0
Term GPA	A	29	7.103	1.5717	2.8	8.8
	B	32	6.813	1.4002	4.4	9.5
	C	33	7.546	1.4813	4.0	9.8
	Total	94	7.160	1.4992	2.8	9.8

[1] *Mean using marks from 0 to 10.*

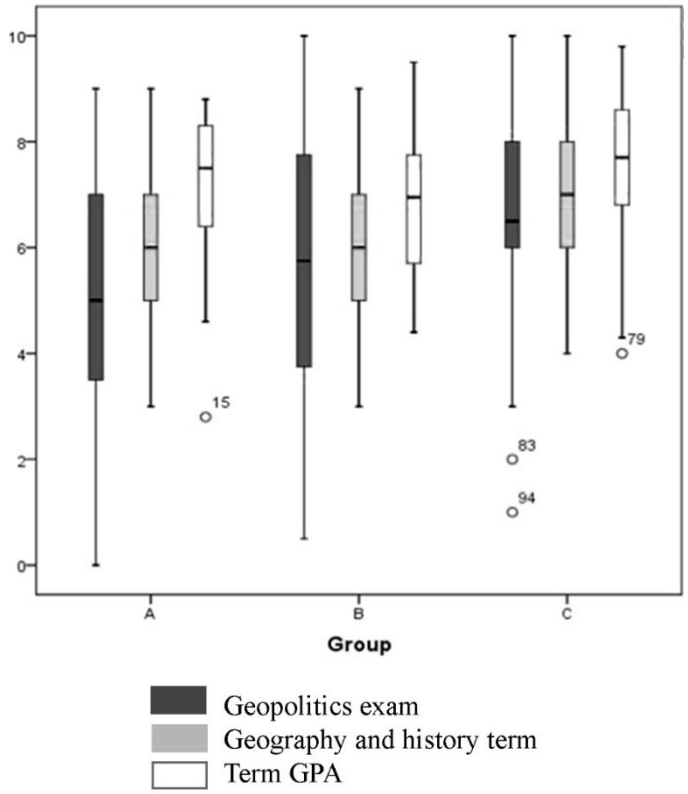

Figure 4. Boxplot of grades by groups. Groups B and C used Web GIS.

Regarding 'Term GPA' there are no significant differences between the mean marks of the three groups. However, in the geography and history term the grade of Group B is lower than that of Group C at 5% (for multiple comparisons ANOVA is needed; 1 factor has been used: the group factor. See Appendix C. ANOVA 1).

Group C has the best grades in the geography and history term and Term GPA. Group A obtained better results than Group B. Group B, as in the case of the average mark in the geography and history term, obtained the lowest marks of the three groups. We can therefore conclude that in terms of grades, Group C obtained the best and Group B the worst average of marks, except for the geopolitics exam (using Web GIS).

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3.2. Results by groups and sex

The descriptive statistics of Web GIS use by sex (Figure 5), for which the contrasts for independent samples are performed to study possible differences in their means, are shown in Appendix B (Test results 1 and 2). The contrasts highlighted show that the groups using Web GIS in all mark categories present equal means with a significance level of 5% (Sig. >0.05). Therefore, in this context and with this error, we don't find any significant difference by sex.

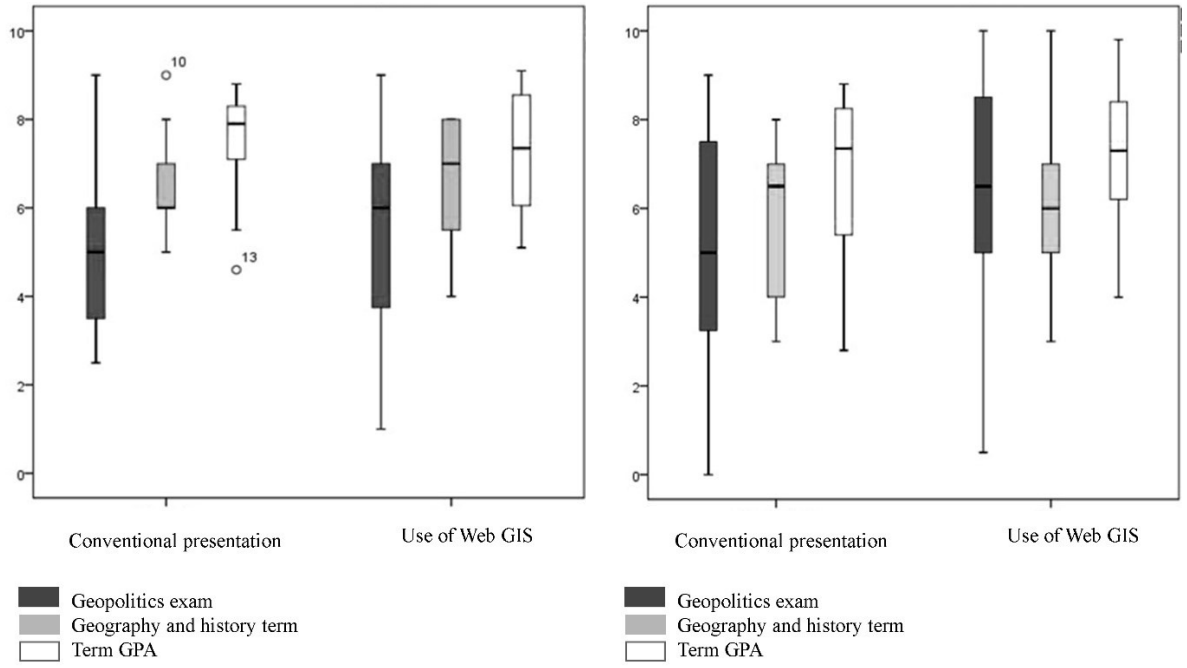

Figure 5. Boxplot of grades by Web GIS use and sex. (**a**) females; (**b**) males.

The basic descriptors separated by sex and group are shown in table 6 and in figure 6.

Table 6. Descriptors by sex and groups

Sex	Concepts of grades	Groups	N	Mean[1]	Sd	Minimum	Maximum
Females	Geopolitics lesson exam	A	13	4.885	1.8389	2.5	9.0
		B	5	3.200	1.7536	1.0	5.5
		C	11	6.455	1.6348	3.0	9.0
		Total	29	5.190	2.0547	1.0	9.0
	Geography and history final term grade	A	13	6.538	1.2659	5.0	9.0
		B	5	5.400	1.6733	4.0	8.0
		C	11	7.091	.9439	5.0	8.0
		Total	29	6.552	1.3252	4.0	9.0
	Term GPA	A	13	7.454	1.3220	4.6	8.8
		B	5	6.280	1.3554	5.1	8.6
		C	11	7.621	1.1748	5.1	9.1
		Total	29	7.315	1.3196	4.6	9.1
Males	Geopolitics lesson exam	A	16	5.188	2.7621	.0	9.0
		B	27	6.056	2.4625	.5	10.0
		C	22	6.523	2.3324	1.0	10.0
		Total	65	6.000	2.5094	.0	10.0
	Geography and history final term grade	A	16	5.813	1.7970	3.0	8.0
		B	27	5.963	1.4272	3.0	9.0
		C	22	6.955	1.8381	4.0	10.0
		Total	65	6.262	1.7164	3.0	10.0
	Term GPA	A	16	6.819	1.7379	2.8	8.8
		B	27	6.911	1.4108	4.4	9.5
		C	22	7.509	1.6376	4.0	9.8
		Total	65	7.091	1.5775	2.8	9.8

[1] *Mean using marks from 0 to 10.*

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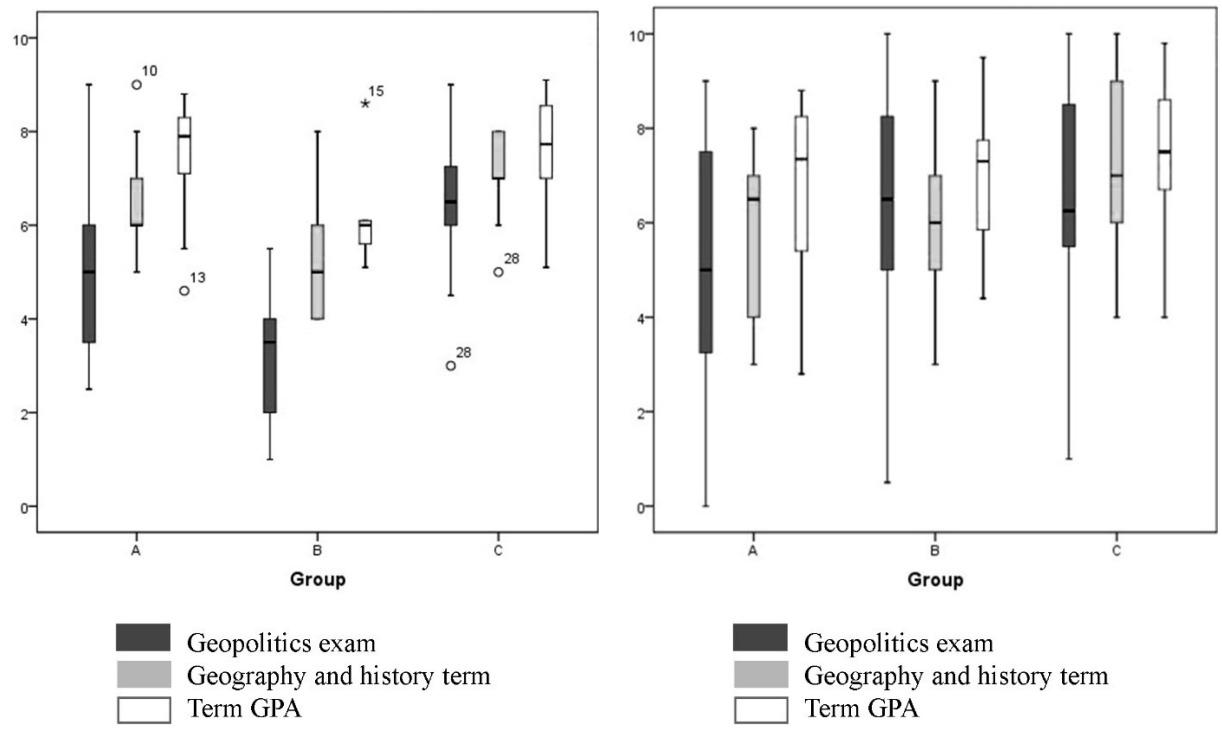

Figure 6. Boxplot of grades by class-group and sex. (**a**) females; (**b**) males.

The variances between males and females in groups A and C are different. Additionally, within Group B the test score is different between females and males, with it being lower among the females in B. Among the females, there are differences between the average mark obtained in the Geopolitics exam in Groups B and C, with the average grade being lowest in Group B. Furthermore, Group B produced significant differences between males and females, on average, in the geopolitics exam. On the other hand, among the females, there are significant differences at 5% between the average grade obtained in group B and those in group C for the exam variable, with the average mark being lower in group B. (ANOVA multiple comparisons with 1 for the group factor; Appendix C ANOVA 2 and 3).

The fact that there are very few females in class B has a significant influence on the sample size and makes the significance less important. Female marks in groups A and C are better; but in group B males have better marks. It is important to consider the fact that group B has more males than females. It seems that females are slightly better than males in terms of the final marks; but these differences are not significant.

The exam results of group A, which had not used Web GIS, are below the others, despite being an academically successful group (as can be seen from Term GPA). In sum, the groups that have used Web GIS have obtained better marks.

4. Discussion and Conclusions

This study has made it possible to compare integration of the first steps Web GIS use in the teaching-learning process with the traditional PowerPoint presentation. For this purpose, a specific class intervention was designed, measuring student grades in a traditional written exam in the same conditions (same time, place, question types and the same teacher to correct all of them). Some of the students prepared for the exam using Web GIS, while others used traditional PowerPoint presentations.

The results produced two main conclusions. First, Web GIS mapping helps K10 students to obtain better grades in a traditional written geography exam. The GPA and geography and history terms showed that group B had the lowest grades. Group B got better geopolitics exam grades using Web GIS than group A, which did not use Web GIS. Thus, Web GIS facilitated group B to obtain better marks than group A in the geopolitics exam. While in the GPA and geography and history grades group A did better. This difference best illustrates our research question that Web GIS use improved group B exam grades, which was applied to geopolitics in this study. Also, the difference between geopolitics' exam grades obtained by groups C and A is wider than the other two grade categories (geography and history term grade and term GPA). Thus, it can be concluded that the use of Web GIS in the geopolitics lesson helped students achieve better marks.

Additionally, students using Web GIS were very surprised to see their replies to Survey123 geolocated on the map when opening their devices, enabling their study at any place and any time. These motivated them to improve their use of web mapping. Presumably, this will help students to improve their web mapping skills as they continue to use Web GIS. Engagement and motivation seen by direct observation are aligned with Ma's (2023) conclusions for geotechnologies. Thus, the study on the use of cloud-based Web GIS in secondary school education has shown its potential to engage students, improve their understanding of spatial concepts, and enhance their digital competencies.

The second conclusion was that there are no differences by sex in Web GIS use. The slight differences found were insignificant. However, as there were few females in our sample, our conclusions on sex must be validated by further research.

In sum, Web GIS use in the classroom seem to improve competencies as in this geopolitics example it has been observed that students became more aware of the world they live in and its effect on their daily lives; and gained technological skills; data management; and procedural

competencies, such as leadership and/or critical thinking. Web GIS allowed us to apply blended learning very easily, as it is possible to work on the cloud anywhere (e.g., at home and at school) using any device and at any time. Web-based GIS is a very practical, active, and motivating way to incorporate digital technology into school education and it also, therefore, should be incorporated into teacher training.

Future research should explore this issue further with a larger sample size and gender balance and additionally explore the use of Web GIS in other curriculum subjects. This study's strength is based on the use of an achievable technology. The intervention does not depend on a particular curriculum content, and geopolitics grade results have been easily compared with term GPA and geography and history area, and it is also part of it . Thus, this comparison method is robust and seems useful for further studies.

Based on the research results, we would like to make the following recommendations for the community of readers and practitioners of GIS in education: (i) To enhance students' understanding of spatial concepts, data analysis, and digital competencies Web GIS seem a useful tool; (ii) Web GIS can be used as an instrument for blended learning, as it can be accessed from anywhere, at any time, using any device; (iii) It is advisable to introduce GIS to students in small steps and sequence the curriculum to encourage students and teachers to use it regularly, rather than just occasionally; (iv) It is necessary to provide training for teachers on how to use Web GIS in the classroom; (v) Encourage further research into the use of Web GIS in education, with larger sample sizes and gender balance, and in other curriculum subjects, to refine our understanding of its potential benefits.

We believe that these recommendations can help to promote the effective integration of Web GIS in education, leading to improved learning outcomes and enhanced digital competencies for students.

Although our study has yielded valuable insights into the improvement in learning results of integrating Web GIS in secondary school education, we acknowledge the limitations inherent in our small-scale investigation. To enhance the generalizability of the findings, future research should adopt a more rigorous approach by utilizing a larger sample size and ensuring improved gender balance. Moreover, it is important to explore the application of Web GIS in other curriculum subjects to obtain a more comprehensive understanding of its potential benefits across diverse educational contexts. We also emphasize the need for a cautious interpretation of our results, as the observed improvements in student grades may be influenced by various factors beyond the sole use of Web GIS. Therefore, we recommend that future studies incorporate control groups and implement more controlled experimental designs to effectively isolate the effects of Web GIS on learning outcomes. By adopting a more systematic and rigorous approach, we aim to expand upon our initial findings and contribute to the continuous advancement of GIS integration in education.

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Appendix A. Type of assessment by grades

Table 7. Type of assessment by grades

Concept grades	Type of assessment
Geopolitics lesson exam	Traditional written exam corrected by the same teacher. Information to be studied is collected by every team, adding peer review corrections after teacher feedback. Group B and C will have this information in the collaborative Web GIS map own students' creation throughout the lesson plan. Group A will have this information in a Google Drive folder, which contains the PowerPoint presentations they made for this purpose. The exam consists of two questions concerning the three categories of each geopolitical area (so they will have to study a total number of eight geopolitical areas and three categories within each area). All exams will have similar questions, but not necessarily the same.
Geography and history final term grade	The final grade will be obtained using all the evaluable activities proposed by the teacher. This evaluation will include knowledge, skills and general competencies that once assessed by the teacher will be transformed into grades, following the Spanish curriculum scale (from 0 to 10). These activities were two written exams per term, participation in debates, oral presentations, exercises (including those to prevent students from disinformation and fake news), and written essays using different procedures: images, texts, and maps analysis.
Grade Point Average (GPA)	The average grade of the entire term's 10 curriculum subjects. This category provides a background to different groups' academic levels.

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Appendix B. Contrast test results

Table 8. Test results 1. Independent sample test, comparing Web GIS use (0-1) and sex. Equal variances are assumed.

Sex	Concepts of grades	Levene's test for equality of variances		t-test for equality of means			95% confidence interval for the difference 0-1	
		F	Sig.	T	gl	Sig. (bilateral)	Lower	Upper
Females	Geopolitics exam	.847	.366	-.714	27	.481	-2.1410	1.0352
Males	Geopolitics exam	.687	.410	-1.506	63	.137	-2.5076	.3520
Females	Geography and history term	.252	.620	-.048	27	.962	-1.0579	1.0098
Males	Geography and history term	.783	.379	-1.210	63	.231	-1.5797	.3884
Females	Term GPA	.118	.734	.505	27	.618	-.7728	1.2767
Males	Term GPA	.606	.439	-.792	63	.431	-1.2712	.5495

Table 9. Test results 2. Independent sample test, comparing Web GIS use. Equal variances are assumed.

Concepts of grades	Levene's test for equality of variances		t-test for equality of means			95% confidence interval for the difference 0-1	
	F	Sig.	T	gl	Sig. (bilateral)	Lower	Upper
Geopolitics exam	.005	.946	-1.913	92	.003	0.0581	.1384
Geography and history term	.000	.998	-.859	92	.01	0.0208	.4044
Term GPA	.068	.795	-.243	92	.04	0.7500	.9867

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Appendix C. Application of ANOVA analysis.

Table 10. ANOVA 1. Multiple comparisons.

						95% confidence interval	
Dependent variable	**(I) Class**	**(J) Class**	**Difference of means (I-J)**	**Dev. error**	**Sig.**	**Lower limit**	**Upper limit**
Geopolitics exam	A	B	-.5577	.6016	1.000	-2.025	.910
		C	-1.4483	.5972	.052	-2.905	.008
	B	A	.5577	.6016	1.000	-.910	2.025
		C	-.8906	.5822	.389	-2.311	.529
	C	A	1.4483	.5972	.052	-.008	2.905
		B	.8906	.5822	.389	-.529	2.311
Geography and history term	A	B	.2629	.3959	1.000	-.703	1.228
		C	-.8621	.3930	.092	-1.821	.096
	B	A	-.2629	.3959	1.000	-1.228	.703
		C	-1.1250[1]	.3831	.013	-2.059	-.191
	C	A	.8621	.3930	.092	-.096	1.821
		B	1.1250[1]	.3831	.013	.191	2.059
Term GPA	A	B	.2909	.3802	1.000	-.636	1.218
		C	-.4429	.3775	.731	-1.364	.478
	B	A	-.2909	.3802	1.000	-1.218	.636
		C	-.7339	.3680	.147	-1.631	.164
	C	A	.4429	.3775	.731	-.478	1.364
		B	.7339	.3680	.147	-.164	1.631

[1] *The mean difference is significant at the 0.05 level.*

Table 11. ANOVA 2. Independent samples; test by sex in each group.

Group	**Concepts of grades**	**Levene's test for equality of variances**		**t-test for equality of means**			**95% confidence interval for the difference Females-Males**	
		F	**Sig.**	**T**	**gl**	**Sig. (bilateral)**	**Lower**	**Upper**
A	Geopolitics exam	2.343	.137	-.339	27	.738	-2.1386	1.5329
B		.729	.400	-2.464	30	.020	-5.2223	-.4889
C		1.418	.243	-.087	31	.932	-1.6742	1.5378
A	Geography and history term	4.309	.048	1.273	26.542	.214	-.4449	1.8968
B		.201	.657	-.791	30	.435	-2.0171	.8912
C		4.213	.049	.282	30.927	.780	-.8515	1.1243
A	Term GPA	1.359	.254	1.086	27	.287	-.5653	1.8354
B		.301	.588	-.924	30	.363	-2.0266	.7644
C		1.779	.192	.201	31	.842	-1.0209	1.2445

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Table 12. ANOVA 3. Multiple comparisons by group and sex.

							95% confidence interval	
Sex	**Dependent variable**	**(I) Class**	**(J) Class**	**Difference of means (I-J)**	**Dev. error**	**Sig.**	**Lower limit**	**Upper limit**
Females	Geopolitics exam	A	B	1.6846	.9208	.236	-.672	4.041
			C	-1.5699	.7168	.113	-3.404	.264
		B	A	-1.6846	.9208	.236	-4.041	.672
			C	-3.2545[1]	.9438	.006	-5.670	-.840
		C	A	1.5699	.7168	.113	-.264	3.404
			B	3.2545[1]	.9438	.006	.840	5.670
	Geography and history term	A	B	1.1385	.6473	.271	-.518	2.795
			C	-.5524	.5039	.849	-1.842	.737
		B	A	-1.1385	.6473	.271	-2.795	.518
			C	-1.6909	.6635	.051	-3.389	.007
		C	A	.5524	.5039	.849	-.737	1.842
			B	1.6909	.6635	.051	-.007	3.389
	Term GPA	A	B	1.1738	.6698	.274	-.540	2.888
			C	-.1671	.5214	1.000	-1.501	1.167
		B	A	-1.1738	.6698	.274	-2.888	.540
			C	-1.3409	.6865	.185	-3.098	.416
		C	A	.1671	.5214	1.000	-1.167	1.501
			B	1.3409	.6865	.185	-.416	3.098
Males	Geopolitics exam	A	B	-.8681	.7876	.824	-2.806	1.070
			C	-1.3352	.8202	.326	-3.353	.683
		B	A	.8681	.7876	.824	-1.070	2.806
			C	-.4672	.7170	1.000	-2.231	1.297
		C	A	1.3352	.8202	.326	-.683	3.353
			B	.4672	.7170	1.000	-1.297	2.231
	Geography and history term	A	B	-.1505	.5260	1.000	-1.445	1.144
			C	-1.1420	.5478	.124	-2.490	.206
		B	A	.1505	.5260	1.000	-1.144	1.445
			C	-.9916	.4789	.128	-2.170	.187
		C	A	1.1420	.5478	.124	-.206	2.490
			B	.9916	.4789	.128	-.187	2.170
	Term GPA	A	B	-.0924	.4962	1.000	-1.313	1.129
			C	-.6903	.5168	.559	-1.962	.581
		B	A	.0924	.4962	1.000	-1.129	1.313
			C	-.5980	.4517	.571	-1.710	.514
		C	A	.6903	.5168	.559	-.581	1.962
			B	.5980	.4517	.571	-.514	1.710

[1] *The mean difference is significant at the 0.05 level.*

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