ISSN: 2633-4828 Vol. 5 No.4, December, 2023

International Journal of Applied Engineering & Technology

ENHANCING GEOGRAPHIC EDUCATION: INTEGRATING GEOGRAPHIC INFORMATION SYSTEMS IN THE CLASSROOM

[1]Ing. Luz Stella Castillo Abella, [2]Dr. Edier Hernán Bustos and [3]Dr. Jaime Duván Reyes Roncancio
[1]Maestría en Educación Universidad Distrital Francisco José de Caldas
[2,3]Professor Universidad Distrital Francisco José de Caldas
[1]lscastilloa@udistrital.edu.co, [2]ehbustosv@udistrital.edu.co and [3]jdreyesr@udistrital.edu.co
[1]ORCID: 0000-0002-4808-5299, [2]ORCID: 0000-0003-0072-8598 and [3]ORCID: 0000-0002-9229-1196

ABSTRACT

This work highlights the importance of teaching Geographic Information Systems (GIS) in geography, emphasizing its fundamental role in systematically analyzing and visualizing geographic data. We propose a pedagogical approach that overcomes traditional barriers by offering a dynamic and contextualized learning experience.

GIS allows students to explore complex geographic data from various sources, such as maps, satellite images, and geographic databases, facilitating understanding trends and patterns. Furthermore, it fosters the development of relevant spatial analysis skills in the modern context. Thus, the relevance of teaching GIS in geography lies in its ability to help understand the dynamic relationship between human and environmental processes, recognizing variations in space and time. GIS enables the analysis and visualization of information crucial for decision-making in resource management, conservation of natural resources, and transportation and logistics planning.

Researchers have found that introducing students to the tools offered by GIS strengthens their theoretical understanding and equips them with practical skills relevant to the workforce. Additionally, since this knowledge applies to advanced geographical research and solving real-world problems, students will be prepared to perform tasks that require spatial analysis competencies and interpretation of geographic data. Thus, teaching SIG in geography enriches academic understanding and equips students with valuable tools to address contemporary challenges in an increasingly interconnected world.

Keywords: Geographic Information Systems, Geography, Teaching, Learning

INTRODUCTION

As new information and communication technologies continue to develop, it is essential to question whether teachers have incorporated the benefits offered by these applications into their knowledge. The latest challenge is to create and adapt pedagogical strategies to apply new technologies to establish a connection between the teacher, the student, and technological developments, thus changing traditional teaching methods (Zanotti, 2020) as an emerging pedagogical proposal.

It is of great importance for teachers who teach geoscience to incorporate appropriate pedagogical processes that ensure the use of technologies and educate a new generation with a broader vision capable of acquiring socially relevant learning, which means that teaching Geographic Information Systems (GIS) should be included, as it is one of the disciplines with the most significant advantages in applying educational areas in geosciences (Díaz, M.G. et al., 2012).

This article aims to present the definition, some applications, and benefits of incorporating GIS as a subject to be taught and learned in the classroom as a pedagogical experience with great potential and high motivation.

Additionally, we conducted an exercise using GIS with census data from Bogotá to create thematic maps that present the information more clearly and understandably. After conducting spatial analysis, these maps depict the population distribution by localities. This exercise proves helpful for decision-making in various fields, such as urban and territorial planning, public services management, environmental management, transportation, agriculture, geology, mining, and other aspects related to population development.

The Relationship between GIS and Geography

Geography and Geographic Information Systems (GIS) are intrinsically linked, as both are employed to understand location and space. Geography is the science of studying the Earth's surface, encompassing physical and human phenomena that occur on it and their interrelationships. In contrast, GIS are systems specifically designed to capture, store, manipulate, analyze, and represent geographic data.

Geography provides the theoretical and conceptual framework to comprehend the Earth's surface's diversity and complexity, while GIS offers technological tools to manage and analyze that information efficiently. Integrating these two fields allows a deeper understanding of spatial patterns, relationships, and trends that influence the physical and human aspects of the geographic environment. Geography and GIS complement each other, providing a more comprehensive and advanced perspective for interpreting and applying geographic data.

Geography and astronomy are sciences on which humanity relies to provide answers to phenomena perceived in nearby and distant environments of the human habitat. Geography originated in ancient Greece, in the 7th century BCE and the 2nd century CE, with schools such as the Ionian, Pythagorean, and Alexandrian. Philosophers from these schools conducted multiple measurements and calculations, leading to relevant concepts, including the proposition of the Earth's sphericity. In the words of Dr. Dante Edin Cuadra, geographical knowledge is as ancient as humanity itself, being an indissoluble part of the development of societies and fundamental in the consolidation and expansion of territories, empires, and states (Cuadra, 2014). It was in the 19th century that its relevance elevated it to the status of a scientific discipline, with the contributions of significant scientific figures such as Humboldt, Ritter, Richthofen, and Ratzel and the inclusion of its teaching in German university institutions.

Numerous paradigms have influenced geographical sciences, some with a more significant impact than others. Depending on the era, Geography adopted different approaches to addressing the study of geographic space, evolving from a concrete discipline to a science. As investigations delved deeper, encountering phenomena that warranted a new discipline or subdivision, various branches tied to basic geographical science emerged. The different components of geography, with their traditional and modern approaches, showcase its paradigmatic evolution.

The article "The Approaches of Geography in its Evolution as a Science" by Dr. Dante Edin Cuadra (2014) presents a broad spectrum of Geography in various fields. It begins with general and systematic approaches, evident in the Middle Ages and the Muslim context. Human ecological geography, a unified notion between nature and humans, paved the way for environmental geography in the 20th century. Cultural geography places us in the scenario of landscape morphology. Quantitative geography arises from the aftermath of geographical spaces left by World War II, proposing techniques and procedures based on logic-mathematics, statistics, and probability, enduring over time due to the abundance of spatial geographical data and technological development. In the 1980s, based on quantitative geography, automated geography emerged, "a geography linked to geoinformatics advances and particularly to the development of Geographic Information Systems" (Buzai, 2005 pp 31-36).

Geographers consider geographical space a complex system derived from the characteristics of natural and cultural elements existing in the Earth's surface environment. This environment encompasses elements above, below, and near the Earth's surface (Frolova, 2006). Natural elements comprise wind, air, mountains, hills, rivers, and rain. Cultural elements are human-made structures like buildings, roads, railways, canals, and dams. In the quest for understanding facts, phenomena, and processes on Earth's surface, spatial analysis employs technological tools. Here, geographic information initially represented in analog format transformed into digital format through Geographic Information Systems (GIS). It began in the 1960s when computers and the first quantitative and automated geography concepts emerged. These research parameters modified the science of geography, driving spatial and quantitative analyses and laying the foundations for GIS. (https://www.aeroterra.com)

Geographic information is increasingly abundant and widely disseminated due to the free access to data. Geographic information systems are required to facilitate the handling and appropriate use of geographic data (Bravo, 2000), which involves storing information, allowing accessible data querying from various study points, analyzing collected data for a better understanding of any project's theme, and most importantly, aiding decision-making -(Alfonso-Sarria, 2006).

On the website of the Geographic Information System of the Education Sector of the Ministry of Education of Colombia, we will find the following definition: "...A Geographic Information System (GIS) allows associating any data with a geographic position. The system shows the location of resources, buildings, and populations and data from municipalities, departments, regions, and the entire country on a single map, combining hardware, software, and geographic data. GIS is used to capture, store, manipulate, analyze, and visualize information in any possible form, in a logical and coordinated manner..." (MinEducación, 2021).

Esri, a leading company, creates GIS (Geographic Information System) software. On its website, http://www.esri.com, we can find the following applications usable for GIS development:

Maps: The software will contain geographic maps with data layers and analyses intended for work. GIS maps are easily shared and accessible practically anywhere for everyone.

Data: GIS integrates different types of data layers using spatial location. Most data has a geographic component, including images and base maps linked to tables and spreadsheets.

Analysis: Spatial analysis allows for the evaluation of suitability and capacity, estimation and prediction, interpretation and understanding, and much more, providing new perspectives to perception and enhancing concepts learned before the use of GIS.

APPS: Apps provide experiences for students, focusing on educational work and bringing GIS to life. GIS apps function practically anywhere: mobile phones, tablets, web browsers, desktop computers, and laptops.

The application of GIS provides many benefits in the teaching and learning process. However, GIS applications should not replace traditional educational resources but rather complement them. The company ESRI (Environmental Systems Research Institute), responsible for the development and marketing of GIS software, highlights the various advantages of using GIS in the educational field:

1. It plays an exciting role in educational curricula. When simultaneous learning is possible for teachers and students, it provides alternative answers to specific problems and facilitates greater engagement with the current situation on our planet,

2. It enhances intellectual capacities, such as critical thinking, spatial intelligence, logical and mathematical intelligence, and the ability to communicate and represent information,

3. Improves control over available information by identifying reliable sources of information, analyzing the origin and quality of data, and combining information from various sources,

4. Develop more excellent skills in the use of computer technology, such as file management, database manipulation, the use of aerial images or orthophotos, spreadsheet operations, and the use of graphics.

SIG is based on solving real-world problems, enabling students to confront everyday situations and act as critical agents of the reality presented to them, actively seeking possible solutions. In other words, in an educational context, GIS provides a simulated environment that facilitates the analysis of spatial relationships and interactions to draw one's conclusions (Boix, 2007). In that sense, integrating new technologies in classrooms poses a real educational challenge for today's educators. This results in increased dynamism and interactivity in the classroom, both from the perspective of knowledge transfer and its production (Sánchez Cabielles, 2014).

The use of ICT in the classroom, especially GIS, is always beneficial; as per Zappettini (2007), it brings several advantages: it provides a powerful and motivating teaching resource; it signifies a departure from traditional (analog) cartography; it allows working at different scales of spatial analysis; it promotes meaningful learning through the creation and processing of georeferenced information; it generates skills to select information from various sources, involving the treatment of conceptual, procedural, and attitudinal contents; it facilitates the representation of data and results, allowing the linking of information from databases to geographical locations.

While GIS commonly serves real-world applications, it is a fundamental pedagogical tool enabling an "intentional, integrated, and meaningful reading of reality at different scales" (Sánchez Cabielles, 2014, pp 12). Their use provides a more dynamic and engaged perspective on our region's social, environmental, or territorial problems. Furthermore, a key feature of GIS is the ease of connecting different types of information through layers. It allows us to compare and analyze diverse information collectively to derive conclusions about processes, causes, and effects, something challenging to achieve through traditional quantitative methods (Zappettini, 2007).

Application of GIS in Geography

The application of GIS with census data offers many possibilities for understanding and addressing urban problems more effectively (Sarría, 2006), such as the following:

1. Population Distribution Analysis, identifying patterns of population density and areas experiencing demographic growth,

2. Socioeconomic Segmentation, where census data is integrated with socioeconomic variables to classify urban areas based on income level, education, and other indicators, facilitates identifying areas that may benefit from specific social development programs,

3. Urban Planning, allowing the evaluation of trends in urban expansion and growth through spatial analysis, identifying areas vulnerable to congestion problems, lack of services, or infrastructure needs,

4. Public Services and Facilities, mapping the distribution of public services (schools, hospitals, recreation centers) in areas of higher population density, identifying accessibility gaps to services, and proposing improvements in urban planning,

5. Mobility analysis and census data can be integrated with transportation information to understand mobility and congestion patterns in various areas of the city, facilitating efficient planning of public transportation routes and identifying areas that require improvements in road infrastructure.

Risk Management, using census data to identify areas vulnerable to natural and socioeconomic risks, facilitating the planning of mitigation and response actions in the event of a disaster.

6. Economic Development, analyzing the distribution of businesses and economic sectors about population density, identifying opportunities for local economic development and job creation.

The application of GIS with census data in Bogotá and any city can provide a deeper understanding of urban dynamics, enabling more effective planning and management of sustainable development and the quality of life of its residents. The census is an indispensable tool for regional development, as it is a crucial political instrument for decision-making and evaluating the impacts of public policies in the medium and long term, allowing the identification of the population's situation in a detailed description of its characteristics (Mazurek, 2012).

The application sample, i.e., the creation of thematic maps, originated in specialized GIS software to process and visualize the coverage of the Corporate Geographic Database - BDGC - information officially provided by the District Planning Secretariat (SDP) and with data produced by the Administrative Department of Statistics (DANE) from the population census of the city of Bogotá for the years 1972, 1991, and 2022.

Table 1. Census data for the population of the city of Bogotá.

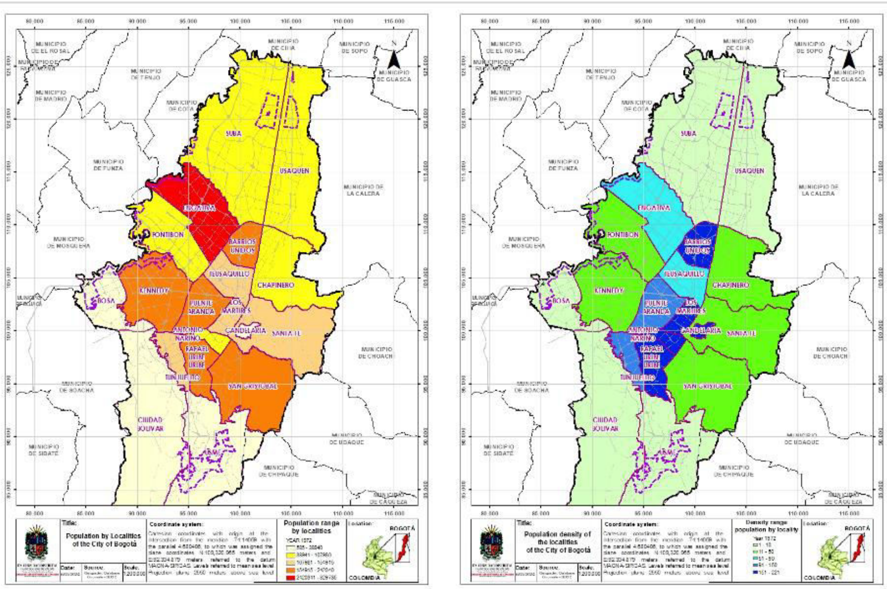
CODE	LOCATION	AREA (HA)	YEAR 1972	YEAR 1991	YEAR 2022	DENSITY 1972	DENSITY 1991	DENSITY 2022
1	Usaquén	6520,14	72104	323229	577693	11,06	49,57	88,60
2	Chapinero	3800,89	90324	95232	175725	23,76	25,06	46,23
3	Santa Fe	4517,06	114783	90914	109462	25,41	20,13	24,23
4	San Cristóbal	4909,85	196866	386372	408112	40,10	78,69	83,12
5	Usme	21506,67	16397	200928	400978	0,76	9,34	18,64
6	Tunjuelito	991,09	154913	214858	183733	156,31	216,79	185,38
7	Bosa	2393,32	25551	262242	731941	10,68	109,57	305,83
8	Kennedy	3858,97	194275	608652	1043623	50,34	157,72	270,44
9	Fontibón	3328,10	90487	221243	397968	27,19	66,48	119,58
10	Engativá	3588,10	329785	601351	820026	91,91	167,60	228,54
11	Suba	10056,05	93213	504100	1264509	9,27	50,13	125,75
12	Barrios Unidos	1190,34	219689	167141	148914	184,56	140,41	125,10
13	Teusaquillo	1419,32	121601	106708	169982	85,68	75,18	119,76
14	Los Mártires	651,40	134779	85711	85083	206,91	131,58	130,61
15	Antonio Nariño	487,95	107977	87367	84298	221,29	179,05	172,76
16	Puente Aranda	1731,11	231317	274472	256160	133,62	158,55	147,97
17	La Candelaria	206,02	38394	11688	18552	186,36	56,73	90,05
18	Rafael Uribe Uribe	1383,41	242038	260251	389783	174,96	188,12	281,76
19	Ciudad Bolívar	13000,26	38938	339196	660230	3,00	26,09	50,79
20	Sumapaz	78096,88	583	2006	3819	0,01	0,03	0,05

Source: Administrative Department of Statistics (DANE).

Below are the thematic maps based on the data from Table 1. The thematic map on the left corresponds to population data, and the thematic map on the right shows population density. These are two distinct, but related concepts used to describe the composition and distribution of the population in a specific geographical area.

The thematic map of population data refers to the total number of people residing in each locality. With this data, we have the absolute size of the population of Bogotá by localities.

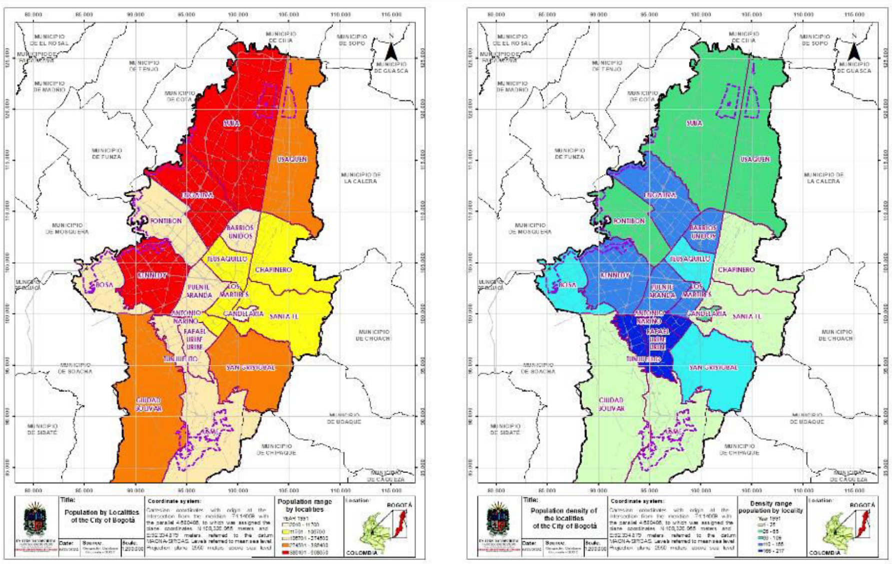
The thematic map of population density is information that relates the number of people living in each locality, considering the surface area in hectares. In other words, it provides the number of people per hectare.



Thematic Map 1 of the city of Bogotá - Year 1972: Population data (left);

Population density (right)

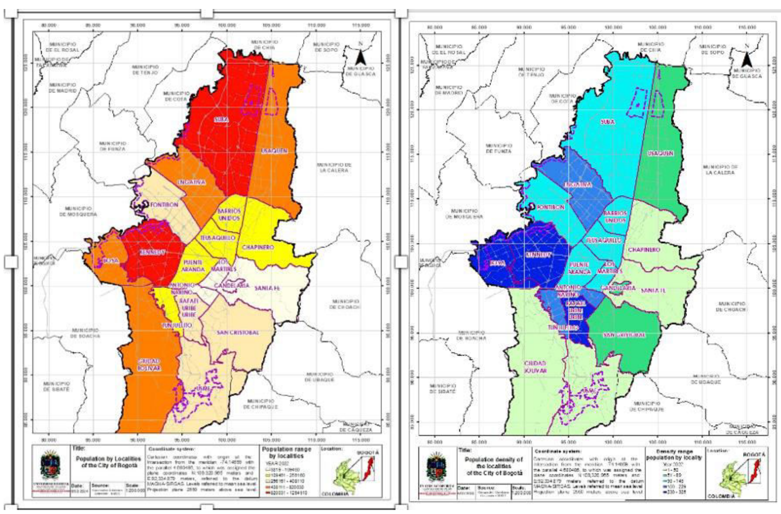
Self-produced using base data from the SDP and DANE.



Thematic Map 2 of the city of Bogotá - Year 1991: Population data (left);

Population density (right)

Self-produced using base data from the SDP and DANE.



Thematic Map 3 of the city of Bogotá - Year 2022: Population data (left); Population density (right)

Self-produced using base data from the SDP and DANE.

RESULTS

Over the years under study, the Sumapaz locality consistently exhibits the smallest population size, attributed to its rural nature characterized by sparse settlements. This demographic trend is evident through historical data indicating that in 1971, Usme had the lowest population count, contrasting with Engativá, which was the most populous. Similarly, in 1991, La Candelaria recorded the smallest population, while Kennedy emerged as the most densely inhabited area. By 2022, La Candelaria remained the least populated locality, while Suba emerged as the most populous. This demographic shift closely links to Suba, Fontibón, and Kennedy's prominence as locales concentrating a significant portion of Bogotá's housing supply, accounting for 65% of available housing in the VIS segment, as outlined in the latest report from the Colombian Chamber of Construction (Camacol).

When examining population density across localities, Usme consistently maintains the lowest density across the years analyzed. Conversely, Antonio Nariño, Tunjuelito, and Bosa emerge as areas with the highest population densities for 1971, 1991, and 2022, respectively. This disparity in population density reflects the varying degrees of urbanization and development across different localities within Bogotá, with specific areas experiencing more concentrated residential settlements compared to others, which is indicative of broader socioeconomic and spatial dynamics shaping the city's demographic landscape.

CONCLUSIONS

GIS is an essential tool that enables geospatial data analysis, management, and visualization, facilitating an understanding of spatial relationships between geographic variables.

The teaching of GIS has the potential to significantly enhance student learning by providing a more practical, relevant, and applied educational experience. Combining new technology, hands-on exercises, and collaboration encourages a comprehensive approach that prepares students to tackle real-world geographic challenges.

In summary, GIS is a valuable pedagogical tool with great potential, enabling the strengthening of teaching, complementing, and deepening theoretical content explained in the traditional classroom.

REFERENCES

Alfonso-Sarria, F. (2006). Sistemas de Información Geográfica. Universidad de Murcia, 239.

Boix, G. &. (2007). Los Sistemas de Información Geográfica (SIG) aplicados a la educación. Las competencias geográficas para la educación ciudadana, 1, 23-32.

Bravo, J. D. (2000). Breve introducción a la cartografía ya los sistemas de información geográfica (SIG). Ciemat.

Buzai, G. D. (2005). Geografía Automatizada, Ciencias de la Información y Ciencias Sociales Integradas Espacialmente. Fronteras, 31–36.

Cuadra, D. E. (2014). Los enfoques de la geografía en su evolución como ciencia. Revista Geográfica Digital. IGUNNE. Facultad de Humanidades. UNNE. Año 11. Nº 21., 1–22.

de Lázaro, M. L. (2006). La utilidad de los Sistemas de Información Geográfica para la enseñanza de la Geografía. Didáctica Geográfica, 106-122.

Frolova, M. &. (2006). Geografía y Paisaje. México: UAM, México.

http://www.esri.com/products.html. (2021).

Mazurek, h. (2012). El censo en Bolivia, una herramientas para el desarrollo. Revista Boliviana de Ciencias Sociales, 239.

MinEducacion. (2021). https://www.mineducacion.gov.co/1621/article-190610.html.

Montes, O. C. (2008). Los sistemas de información geográfica como medio didáctico en la enseñanza de la geografía.

Pardo-García, S. M. (2017). Los Sistemas de Información Geográfica (SIG) en la docencia del urbanismo: el caso de España. Arquitectura y Urbanismo, 38(2), 63-72.

Ruiz, Á. L. (2018). Los itinerarios didácticos en la enseñanza de la geografía. Reflexiones y propuestas acerca de su eficacia en educación. Revista UNES. Universidad, Escuela y Sociedad., 5, 55-81.

Sánchez Cabielles, P. (2014). TIC y didáctica de la Geografía: el papel del SIG en la Educación Secundaria.

Zanotti, A. &. (2020). Experiencias innovadoras TIC en educación no formal. Question/Cuestión, 1(65), 261.