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DEVELOPING AN OPEN-SOURCE TOOL FOR COLLABORATIVE MAPPING: PROCESS, CHALLENGES AND SOLUTIONS

[a]**Gabriel Orozco**, [b]**Pilar Díaz-Cuevas**
Departamento de Geografía. Facultad de Geografía e Historia. Universidad de Sevilla.
c/ Doña María de Padilla, Casco Antiguo, 41004 Sevilla. España
[a]gorozco1@us.es, [b]pilard@us.es

ABSTRACT

Volunteered Geographic Information (VGI) has redefined the practices of geospatial data collection and utilization, by promoting collaboration and democratizing access to geographic information. However, existing tools present notable limitations regarding accessibility, adaptability, and cost, restricting their use in communities and research projects with limited resources. This article presents NexusMap, an open-source tool designed for the collection, visualization, and management of collaborative geographic information. Its development has addressed key technical and methodological challenges, such as the creation of modular and scalable architecture, accessible interfaces for users without technical training, and essential functionalities such as data validation and interoperability through open geospatial standards. NexusMap is easily adaptable to different types of projects, fostering inclusive and flexible participation. The plugin was evaluated through tests conducted with undergraduate and postgraduate students, including participants with and without prior GIS experience. The results indicate a high level of acceptance: students without technical training gave an average score of 4.49 out of 5 across all items, while advanced users rated the plugin with an average of 4.25. However, feedback from advanced users highlights priority areas for improvement in future versions. These insights suggest that future updates should prioritize these aspects to enhance the tool's suitability for more demanding professional environments. The source code is available at the NexusMap GitHub repository: https://github.com/EscalaDigital/nexusmap.

Keywords: Volunteered Geographic Information; geospatial data; open-source GIS; collaborative mapping; WordPress plugin; geospatial interoperability

DESARROLLO DE UNA HERRAMIENTA DE CÓDIGO ABIERTO PARA CARTOGRAFÍA COLABORATIVA: PROCESO, DESAFÍOS Y SOLUCIONES

RESUMEN

La Información Geográfica Voluntaria (VGI) ha redefinido las prácticas de recopilación y uso de datos geoespaciales, promoviendo la colaboración y democratizando el acceso a la información

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geográfica. Sin embargo, las herramientas existentes presentan notables limitaciones en cuanto a accesibilidad, adaptabilidad y costo, lo que restringe su uso en comunidades y proyectos de investigación con recursos limitados. En este contexto, este artículo presenta NexusMap, una herramienta de código abierto diseñada para optimizar la recopilación, visualización y gestión de información geográfica colaborativa. NexusMap permite la participación de usuarios sin formación técnica y es adaptable a los requisitos específicos de una amplia variedad de proyectos. Su desarrollo ha abordado retos técnicos y metodológicos clave, como la creación de una arquitectura modular y escalable, el diseño de interfaces accesibles para usuarios sin formación técnica y la integración de funcionalidades esenciales como la validación de datos y la interoperabilidad mediante estándares geoespaciales abiertos. NexusMap se adapta con facilidad a distintos tipos de proyectos, promoviendo una participación inclusiva y flexible. El plugin fue evaluado mediante pruebas realizadas con estudiantes de grado y posgrado, incluyendo participantes con y sin experiencia previa en SIG. Los resultados muestran un alto nivel de aceptación: los estudiantes sin formación técnica otorgaron una puntuación media de 4,49 sobre 5 en todos los ítems, mientras que los usuarios con experiencia avanzada lo evaluaron con una media de 4,25. No obstante, los comentarios de estos últimos señalan líneas prioritarias de mejora para futuras versiones. Estas aportaciones sugieren que las próximas actualizaciones deberían centrarse en dichos aspectos para mejorar la idoneidad de la herramienta en entornos profesionales más exigentes. El código fuente está disponible en el repositorio de GitHub de NexusMap: https://github.com/EscalaDigital/nexusmap.

Palabras clave: Información Geográfica Voluntaria; datos espaciales; SIG de código abierto; cartografía colaborativa; *plugin* de WordPress; interoperabilidad geoespacial

1. Introduction

Collaborative mapping has emerged as an essential tool for addressing a wide range of global and local challenges. Commonly referred to as Volunteered Geographic Information (VGI), this approach empowers individuals without specialized technical training to contribute to the creation of geographic databases using web-based applications, mobile devices, and digital tools. As early as 2007, Goodchild underscored the transformative potential of VGI, emphasizing its role in reshaping the generation and utilization of geospatial data while promoting active and democratized participation in the production of geographic information (Goodchild 2007).

The versatility of these tools for data collection has, in many cases, enabled public reporting and the addressing of a broad range of social and environmental challenges. OpenStreetMap (openstreetmap.org) serves as a prominent example (Antoniou *et al.* 2017). In emergency management, for instance, collaborative mapping facilitates the rapid collection and dissemination of data, as demonstrated during the 2010 Haiti earthquake, where volunteers used Ushahidi (ushahidi.com) to map affected areas, providing critical information to humanitarian aid organizations (Meier 2015). In public reporting, these tools empower citizens to report incidents in real time. This was exemplified by the Ushahidi platform, which was employed to map reports of post-election violence in Kenya in 2008, marking the beginning of similar initiatives in other countries (Ajao & Wielenga 2017).

In environmental conservation, collaborative mapping has proven highly valuable for tracking ecological issues and monitoring human activities. One notable example is the Water Conflicts Map of Andalusia in Southern Spain (rediam-indalo.cica.es/mccaa/), which enables the visualization and understanding of challenges related to water management in the region (Pedregal *et al.* 2020). Collaborative mapping also plays a significant role in urban planning. Initiatives such as the "Mapa Barcelona + Sostenible" (bcnsostenible.cat) project have allowed citizens to contribute information on mobility and sustainability, informing the development of more inclusive and effective urban policies (Ajuntament de Barcelona, 2018). In public health, it has been used to track disease outbreaks, as demonstrated during the 2014 Ebola outbreak in West Africa, where collaborative maps were created to identify cases and coordinate resources efficiently (Lee-Cruz *et al.* 2021). Despite these advantages, collaborative mapping faces multiple technical, institutional, and social challenges that limit its broader adoption and integration into official frameworks. Issues such as lack of standardization, interoperability difficulties, data quality concerns, and high development costs pose significant barriers. Furthermore, sustainability remains a key issue, as many collaborative mapping projects struggle to maintain long-term engagement and institutional support.

A clear distinction between PPGIS, VGI, and collaborative mapping is warranted to delimit the scope of this study. PPGIS (Public Participatory GIS) establishes the methodological framework for channeling citizen input into spatial decision-making (Sieber 2006), whereas VGI (Volunteered Geographic Information) denotes geographic data generated spontaneously and altruistically by non-specialist users (Goodchild 2007). Collaborative mapping emphasizes the shared, real-time construction and editing of maps, underscoring the co-creation and validation of geographic content (Elwood 2008). This article focuses on solutions for VGI generation within collaborative mapping tools—examining the collection, validation, and visualization of volunteered geographic data and offering researchers or NGOs simple, functional means to produce thematic information—rather than addressing the full PPGIS methodology, which encompasses participatory design phases, qualitative analysis, and institutional decision-making.

This study proposes the development of an open-source tool for collecting, visualizing, and sharing volunteered geographic information. The following sections will examine the context and main challenges affecting collaborative mapping initiatives, outline the specific objectives of this research, and describe the methodology used in the development of the proposed tool. Subsequently, the results of the implementation will be presented, along with a case study that demonstrates its applicability in a real-world context. Finally, the findings will be analyzed in the discussion, and the study will conclude with key insights and perspectives for future research.

2. Context and Challenges

Despite its significant potential, collaborative mapping faces considerable challenges stemming from various factors. In many cases, custom developments or tools not specifically designed for information dissemination are employed, resulting in a lack of standardization in the generated data (Geoinnova n.d., Senaratne *et al.* 2016, Ahmad *et al.* 2022). This hinders the integration of such data with Geographic Information Systems (GIS), directly impacting the utility and scope of collaborative mapping projects and limiting their broader adoption in diverse contexts.

Additionally, several authors have highlighted the difficulty of integrating collaborative data into institutional systems that require high levels of standardization, interoperability, and consistency, such as Spatial Data Infrastructures (Genovese & Roche 2010, Olteanu-Raimond *et al.* 2017, Pedregal *et al.* 2015, Schade & Tsinaraki 2016, See *et al.* 2016, Pedregal *et al.* 2024, Osorio Arjona *et al.* 2022). These infrastructures, designed to manage geographic information adhering to strict technical standards, face significant barriers in incorporating data generated through diverse tools and methodologies (Craglia & Annoni 2006), often developed independently and lacking alignment with institutional requirements. This creates a gap between the potential of collaborative data and its capacity to be integrated into official platforms.

An further challenge lies in the skepticism regarding the quality of data produced by non-expert users. The perception that collaborative data may lack precision or fail to meet established quality standards, due to the varying expertise levels of contributors, has led to hesitation among institutions that traditionally depend on controlled and verified data sources. While such concerns are not unfounded, they often undervalue the potential of collaborative data as a valuable complement to official sources (García-Araque 2020, Goodchild & Li 2012, Foody *et al.* 2013).

In addition to the challenges mentioned, custom development often requires the engagement of specialists in programming, with expertise in cartography or GIS, as well as skills related to design. This is compounded by the issue highlighted in the previous paragraph, as those involved in the tool's development must ensure that the data formats adhere to existing standards. Furthermore, significant investment is required in technological infrastructure to host and maintain the tool. Collectively, these factors can result in substantial costs, potentially posing a significant barrier for many research or management projects, particularly those with limited resources or funded by non-profit organizations.

Although various software platforms are available, many require costly licenses or offer limited customization and scalability. For instance, platforms such as ArcGIS Online or Mapbox necessitate significant investments when used beyond their free capacities, making them inaccessible to communities with limited resources (Antoniou & Skopeliti 2015). On the other hand, free solutions like Google My Maps, while useful, exhibit functional limitations that hinder their adaptation to more ambitious projects. Table 1 provides a comparative overview of leading VGI and collaborative mapping platforms (highlighting cost, openness, ease of use, self-hosting capability, form customization, and installation ease) to illustrate how current tools align (or fall short) with the needs for accessible, adaptable solutions. The analysis highlights that many of the available tools are paid or follow premium models, and only a few, such as OpenStreetMap, Epicollect5, KoBoToolbox or uMap, offer free access with fully or partially limited functionalities. In terms of open-source availability, few solutions guarantee it, which restricts customization and technological independence. Notable exceptions include OpenStreetMap, Ushahidi, KoBoToolbox and uMap. Ease of use varies significantly: tools like Google My Maps or Carto are accessible to users without technical training, whereas others, such as Survey123, require specialized knowledge. Self-hosting is only supported by solutions like KoBoToolbox, MapHub or uMap. Furthermore, form customization, an essential feature in participatory contexts, is well implemented in platforms such as Survey123, KoBoToolbox, and Spotteron, unlike more limited options such as Google My Maps or OpenStreetMap.

This context underscores a critical issue: the lack of flexible and accessible tools, particularly in the domain of open-source software, that can be configured and utilized by users without technical expertise (Pedregal *et al.* 2024, Vahidnia & Vahidi 2021).

Table 1. Comparative Overview of Collaborative Mapping Platforms

Tool	Cost	Open Source	Ease of Use	Self-hosting	Installation Ease	Form Customization
OpenStreetMap	Free	Yes	High	Yes	Medium	Low
Mapbox	Paid	No	Medium	No	–	Medium
Carto	Paid	No	High	No	–	High
Google My Maps	Free	No	High	No	–	Low
Survey123 (Esri)	Paid	No	Medium	No	–	High
Felt	Paid	No	High	No	–	Medium
Ushahidi	Paid	Yes	Medium	No	–	High
KoBoToolbox	Paid	Yes	High	Yes	Medium	High
Epicollect5	Free	Yes	High	No	–	High
Open User Map Pro	Paid	No	High	Yes	High	High
MapHub	Paid	Yes	High	Yes	Medium	Medium
Mapseed	Paid	No	Medium	No	–	High
Spotteron	Paid	No	Medium	No	–	High
ArcGIS Online	Paid	No	High	No	–	Medium
uMap	Free	Yes	High	Yes	Low	Medium

Source: Authors' own elaboration

Compounding these challenges is the risk of platform abandonment, often resulting from a lack of sustained interest or the perception that a project has become obsolete. This phenomenon is situated within the framework of "liquid modernity" (Bauman 2000), which describes an era characterized by rapid change, ephemeral commitments, and challenges in sustaining continuity within collective initiatives. In such a context, collaborative projects must navigate the difficulty of maintaining relevance in an environment where participants' priorities are prone to frequent shifts. Contributing factors such as the absence of institutional support, unresolved technical challenges, and inadequate financial resources further intensify the risk of discontinuity and eventual project abandonment.

A critical aspect in the design of collaborative mapping tools is the identification of the minimum requirements necessary to ensure their functionality and utility. Each project presents unique needs, and the tool must be sufficiently flexible to adapt to these specific contexts. Key requirements include the ability to collect data through dynamic and intuitive forms, the interactive visualization of data on maps using libraries such as Leaflet or OpenLayers, and the efficient management of users with different roles and permissions (Pedregal *et al.* 2024). Furthermore, implementing robust validation and moderation processes is essential to ensure the quality of contributed data. Interoperability should also be prioritized by enabling data export in standard formats such as GeoJSON, GML, or KML, and through services like WMS (Web Mapping Services), WMTS (Web Map Tile Service) and WFS (Web Feature Service), facilitating their reuse in other systems (Open Geospatial Consortium 2020). Additionally, accessibility and ease of use must be emphasized by designing interfaces tailored for users without technical expertise, ensuring they can interact with the tool efficiently (Vahidnia & Vahidi 2021).

These elements underscore the importance of developing tools that combine accessibility, flexibility, and technical robustness to ensure their adoption in a wide range of projects. In this regard, the emergence of artificial intelligence (AI) can play a pivotal role in enhancing the quality and interoperability of collaborative data, directly addressing some of the challenges mentioned above. As noted by Orozco and Díaz-Cuevas (2024), machine learning algorithms can automate the validation of data generated by non-expert users, detecting inconsistencies and improving their reliability before integrating them into broader systems, such as Spatial Data Infrastructures (SDIs). Moreover, AI can facilitate the standardization and harmonization of data from diverse sources, adapting them to formats compatible with the technical standards required by institutional platforms. It can also provide tools to personalize the end-user experience, simplifying interaction with collaborative mapping tools and enabling individuals without technical expertise to actively participate in complex projects. However, its implementation presents significant challenges, ranging from the selection of appropriate technologies to the design of architectures capable of supporting the tool's growth and continuous adaptation.

This highlights the critical need to develop tools that are more accessible, functional, and adaptable (Roche *et al.* 2013). The lack of standardization, skepticism regarding data quality, high development and implementation costs, and long-term sustainability pose significant barriers to the adoption of these technologies in diverse projects. A collaborative map must enable participation from users without technical expertise, as most users of such tools typically lack advanced technical knowledge (Vahidnia & Vahidi 2021). Equally important, however, is that its implementation remains straightforward and adaptable to the specific needs of each project. This dual focus, usability and flexibility, ensures that the tool not only fosters citizen participation and the democratization of access to geographic data but also facilitates its integration into projects with varied technical requirements and limited resources.

Given these challenges, this study proposes the development of an open-source solution designed to enhance accessibility, interoperability, and long-term sustainability. The following section presents the objectives of this initiative.

3. Objectives

This study aims to contribute to addressing some of the challenges by developing and implementing an open-source tool for the collection, visualization, and sharing of volunteered geographic information. The tool is designed to be accessible to users without technical training and adaptable to collaborative mapping projects of varying nature. To achieve this goal, the solution must be generic, adaptable, and flexible, ensuring it reaches the widest possible audience of users who can implement it in their research.

To achieve this objective, the following steps have been undertaken:

- Identify the minimum requirements and functionalities that a volunteered geographic information tool must possess to establish the foundational framework for its development.
- Adopt a technology that supports modular and scalable architecture, enabling customization to meet the specific needs of diverse users and projects.
- Implement the tool using accessible technologies and design principles, ensuring that individuals without programming knowledge can configure and use it effectively.

4. Methods

In the first stage (Table 2), the minimum requirements for a VGI tool will be defined. The greatest obstacle to the development of collaborative mapping projects by non-expert users is the lack of tools that can be tailored to their specific needs. Therefore, it is essential to establish the minimum requirements the tool must meet, ensuring they are robust enough to accommodate the widest possible range of studies. Additionally, the tool will be open-source software, allowing users to modify the code and add custom functions as needed.

The findings of Pedregal et al. (2024) have been considered. This study thoroughly analysed 43 collaborative web maps collected online (https://idus.us.es/items/bb1c7e7d-fbd9-4b4f-8864-103013c453d8). Moreover, the requirements proposed by Orozco and Díaz-Cuevas (2024) have also been incorporated to ensure the comprehensiveness and adaptability of the tool.

Once the theoretical requirements for such a tool have been established, it becomes necessary to select the appropriate technology to enable its development (Stage 2). This involves choosing the programming language, evaluating the potential integration of GIS or other systems to enhance usability, and selecting frameworks, libraries, or other technical tools that ensure a practical, functional outcome aligned with the defined needs. Moreover, the benefits and capabilities of the selected technology will be thoroughly analysed and compared with other available options to ensure the most suitable choice for achieving the project objectives.

Based on the selected technology, Stage 3 will focus on designing a software architecture that ensures the long-term implementation and maintenance of the developed code. Developing software without a well-defined architecture can lead to disorganized code that is difficult to maintain and scale. Inadequate architecture increases the likelihood of performance issues, bugs, and challenges in implementing new features. For the tool being developed, such shortcomings could severely compromise its sustainability and long-term evolution. A robust architecture is therefore essential to support the tool's functionality, adaptability, and future enhancements.

In stage 4, the construction of the tool will be undertaken. During this stage, the development process will be addressed, highlighting the challenges encountered and the solutions implemented. Emphasis will be placed on usability, ensuring that the interface is intuitive for non-technical users. Responsive design elements will be integrated, and performance will be optimized to ensure a seamless experience across various devices and platforms.

Finally, in Stage 5, a testing and evaluation process will be conducted on the developed software to ensure it functions correctly, is secure, and meets the established objectives. Each of these phases will now be discussed in greater detail.

Table 2. Methodological Stages

Stages and Objectives	Main Activities	Expected Outcomes
Stage 1: Defining Minimum Requirements (Establish functional and open-source conditions)	- Identify key needs - Review similar tools - Establish minimum requirements	List of requirements
Stage 2. Selecting Technology (Choose appropriate programming language, frameworks, and/or components)	- Evaluate technological options - Compare performance, support, and adaptability - Select the most suitable alternative	Technological framework
Stage 3. Designing Architecture (Organise software for maintenance and future improvements)	- Define development model (presentation, logic, data) - Establish coding patterns and standards	Coherent and maintainable architecture
Stage 4. Build the Tool (Develop functionalities, interface, and optimize performance)	- Program key modules - Design an intuitive interface - Optimize code for performance	Functional tool
Stage 5. Testing and Assessment (Verify functionality, security, and objectives)	- Conduct unit and user testing - Resolve identified issues	Reliable and validated final product

Source: Authors' own elaboration

4.1. Defining Minimum Requirements

Based on the study conducted by Pedregal *et al*. (Pedregal *et al.* 2024), which analysed 43 collaborative web mapping tools, and the subsequent work by Orozco and Díaz-Cuevas (2024), which compiled a set of requirements derived from the initial study, a range of functionalities has been identified. This enables a tool to effectively address most use cases requiring collaborative cartography solutions. Among the most prominent functionalities are data collection, data visualization, user management, validation and moderation, interoperability, and customization.

Regarding data collection, the data entry form must be clear and user-friendly to ensure that the end user can input values without difficulty. In this work the development of a tool must enable the dynamic creation of such forms, which will involve designing a form creation tool and a system for managing the data entered it.

In terms of data visualization, shared data should be represented through interactive maps utilizing cartographic libraries such as Leaflet or OpenLayers, or through integrations with open API services like Google Maps. This approach ensures a visual representation that facilitates the dissemination, analysis, and decision-making processes based on the user-generated data.

With respect to user management, the tool should include an efficient user management system that allows for the establishment of different access levels and permissions. This ensures that only authorized users can add, edit, or manage the contributed information.

For validation and moderation, it is essential to implement processes that ensure the quality and accuracy of user-contributed data (Geoinnova n.d., Sánchez *et al.* 2012). These processes may include manual reviews or automated systems capable of assessing the feasibility and reliability of the data prior to publication.

Interoperability is another critical aspect, as the ability to export data in standard formats such as GeoJSON (GeoJSON n.d.) greatly enhances the tool's utility. This feature enables seamless integration with other systems and applications, thereby improving the efficiency and effectiveness of information management.

Customisation is also a valuable feature, allowing users to adapt the tool to their specific requirements. This may involve enabling the modification of visual styles, adding custom base maps or overlay layers, and integrating advanced functionalities such as address-based search. Additionally, the tool should support user-defined layers, further enhancing its flexibility and scalability to address diverse project contexts and needs.

4.2. Selecting technologies

During the analysis phase, various alternatives for developing the final tool were evaluated. One initial option was to develop the tool from scratch; however, this approach presented several drawbacks. Among these, a significantly longer development time was identified due to the need to create a complete code base and design the tool in its entirety (Sommerville 2016, Cantú-Mata *et al.* 2018). Moreover, this approach would require a higher level of technical knowledge from the end user. Since the tool would be designed to operate on a server, users would need to manage its deployment, including connecting the backend to a custom database. Although part of the process could be simplified through a form allowing users to input data such as username, password, and database name, the user would still face the task of creating and configuring the database, thereby adding a significant level of complexity.

For these reasons, the use of an external API, such as those provided by online map service providers, was considered. This alternative offered certain advantages, such as automating parts of the system through the provider's infrastructure, which could simplify management for the user. However, significant limitations were also identified, including the need to obtain and configure an access key (API Key), a process that may prove challenging for some users. Additionally, external APIs are often subject to free usage limits, potentially resulting in additional costs when these limits are exceeded. These restrictions ultimately led to this alternative being dismissed.

During the analysis, GIS platforms were also considered as a foundation for development; however, their complexity and the requirement to ensure online data access rendered them less suitable for the intended purpose. Ultimately, the decision was made to create a plugin for WordPress, an open-source content management system (CMS) initially launched in 2003 and widely adopted for its exceptional flexibility, scalability, and user-friendliness. This platform, supported by an active community of developers and contributors, simplifies the creation and management of websites through an intuitive interface and a robust ecosystem of themes and plugins. Furthermore, its compatibility with most servers and hosting environments provides a versatile solution for projects of varying scale and scope.

According to W3Techs, WordPress is used by 43.5% of all websites on the Internet (Kinsta, n.d.), which corresponds to approximately 861million websites out of an estimated total of 1.98 billion. This widespread popularity and accessibility make WordPress an appropriate choice, providing users with a universal platform that offers quick and easy access to the necessary tools without requiring advanced technical knowledge. However, basic knowledge of WordPress installation and management will still be necessary. This requirement, while seemingly at odds with the goal of simplifying the creation of collaborative maps for users, is not entirely so. A minimum level of technical understanding is inevitable, but by leveraging WordPress, users gain access to a system that is highly documented and supported by numerous resources. Moreover, many web servers offer automated installers, further reducing the technical complexity for users and making the system more accessible overall.

Within the broader WordPress landscape, where the official plugin repository features several mapping and form builders, tools like WP Google Maps, Leaflet Map, and various Gravity Forms add-ons deliver geospatial visualization and data entry with varying levels of functionality. However, many of these options require paid upgrades for many of the aforementioned features, lack true interoperability, or impose manual adjustments that can be overwhelming for non-technical users. NexusMap addresses this niche by combining point-based Volunteered Geographic Information collection, on-the-fly GeoJSON output, and a minimal-configuration front-end, all under an open-source license. At the same time, building on WordPress brings its own responsibilities: continuous testing against core and theme updates, strict adherence to security best practices for plugin development, and periodic maintenance to guard against compatibility issues and vulnerabilities (WordPress Foundation, n.d.).

4.3. Designing and Implementing the Plugin

The design of the plugin focused on ensuring scalability, ease of use, and compatibility with a standard WordPress installation. Additionally, future updates were considered, requiring a development approach oriented towards long-term adaptability. It is essential to create a software design that is maintainable, well-structured, and thoroughly documented, ensuring the sustainability of the application over time.

4.3.1. Plugin Structure

WordPress follows a structure similar to the Model-View-Controller (MVC) pattern (Gamma *et al.* 1994), which has proven to be a robust framework for separating business logic, user interface, and interaction control. This approach not only simplifies software management and scalability but has also been widely adopted across various domains (Necula 2024). This structure is particularly relevant for collaborative mapping tools, where managing large volumes of data while maintaining an intuitive interface is critical. However, the MVC pattern is not strictly applied in WordPress. While influenced by this schema, WordPress adopts its own unique approach (Blanco n.d.). It features a modular and extensible architecture that enables the addition of functionalities through a hook-based structure (actions and filters). These hooks serve as access points, allowing developers to integrate their plugins with the core system seamlessly (Kinsta n.d.).

The structure developed for the NexusMap plugin was designed following the best practices recommended by the WordPress community. A clear separation was implemented between the code intended for the admin panel and the visible on the front-end. This division is reflected in two main directories: admin and public (Figure 1). This approach allows for independent management of the plugin's internal functionalities, such as settings and data handling, and those that directly interact with end users on the website. Such delineation facilitates the development of new features while preventing interference between the administrative and public-facing areas.

```
nexusmap/
├── admin/                 # Code for the admin panel
│   ├── css/               # Styles for the admin
│   ├── js/                # Scripts for the admin
│   ├── views/             # Admin view templates
│   └── class-nm-*.php     # Classes for admin functionality
├── includes/              # Core plugin code
│   ├── models/            # Data models
│   └── class-nm-*.php     # Main classes
├── public/                # Code for the frontend
│   ├── css/               # Public styles
│   ├── js/                # Public scripts
│   └── views/             # Public templates
└── nexusmap.php           # Main plugin file
```

Figure 1. Main Structure of the Plugin
Source: Authors' own elaboration

An additional folder named includes was established to store the general classes and components required for the plugin's functionality. Within this folder, a specific subdirectory named models was created to organize the data models, following the Model-View-Controller (MVC) design pattern. This approach enhances code organization and facilitates future scalability by enabling the distinct layers (data, logic, and presentation) to operate independently while maintaining coordination. This separation ensures cleaner code management, simplifies debugging, and supports the integration of new features.

The management of static resources was structured to prevent conflicts between the backend and front-end. CSS, JavaScript, and image files were organized into dedicated directories within the admin and public folders. Views, on the other hand, were grouped in a separate directory named views, providing a centralized location for visual elements. This organizational scheme simplifies both maintenance and the identification of resources required for each section, ensuring a clear separation of concerns and improving overall efficiency in development and debugging processes.

Regarding naming conventions, a system was adopted that adheres to the standards established by WordPress (WordPress Foundation n.d.). PHP classes within the plugin were named using the prefix class-nm-, where nm represents the plugin name (NexusMap). This prefix ensures the uniqueness and clear identification of the classes, minimizing the risk of conflicts with other plugins. This approach enhances code clarity, making it easier to read and understand.

The main plugin file, nexusmap.php, was placed at the root of the project and defined as the entry point. This file contains the plugin's basic information, initializes key dependencies, and establishes the general system structure. This arrangement aligns with WordPress's recommended practices, ensuring that the plugin is modular, adaptable to future requirements, and scalable for use in various environments.

4.3.2. Database

WordPress provides the $wpdb class, which enables the creation of objects to interact with the database securely and efficiently (database model). This class allows access to WordPress's standard database structure and supports the creation and management of custom tables specific to the plugin under development.

One of the advantages of using WordPress for developing a collaborative mapping plugin is its built-in user management system. This includes functionality for user registration, login, password encryption, and more. By leveraging this system, development time is significantly reduced, allowing the focus to shift toward creating the plugin's unique features. Another useful feature of WordPress is the wp_options table, which can store various configuration elements for both the WordPress system and its installed plugins. In this case, this table is utilized to store settings related to tool selection by the site administrator. Specifically, it saves configurations for elements displayed on the map, such as functional buttons (*e.g.*, data download, search, or layer addition) and information about selected layers. This includes both base layers and overlays chosen by the administrator for display on the map. This integration simplifies configuration management while maintaining flexibility for customization.

Within the plugin's structure, two custom tables are required. The first table will store the structure of the form designed by the site administrator, while the second table will record the data submitted by users. The latter will not only include the data collected from the form but also additional information such as the user who submitted the data, the status of the submission (approved or rejected), the upload date, and the specific form associated with the submission. This allows for flexibility in handling either a single form or a conditional setup involving two distinct forms. These tables are created within the WordPress system upon activation of the plugin, using the NM_Activator class (Figure 2), which, in turn, invokes the implemented model. This ensures that the database structure is established dynamically and in alignment with the plugin's requirements.

```

class NM_Activator {

    public static function activate() {
        // Create necessary database tables
        $model = new NM_Model();
        $model->create_forms_table();
        $model->create_entries_table();

        flush_rewrite_rules();
    }
}

```

Figure 2. Creation of the Tables Required for Plugin Operation
Source: Authors' own elaboration

4.3.3. Development of Functionalities

The plugin must address all the fundamental requirements for a collaborative mapping tool as outlined in Section 4.1 of this article. To achieve this, this section breaks down the core functionalities and the technical implementations designed to meet the stated objectives.

Figure 3 illustrates the operational dynamics of the plugin, with a focus on cartography. The theoretical core of the system is cartography, which serves as the bridge between back-end processes and front-end interactions. A cartographic system has been implemented using Leaflet JavaScript library as its foundation. This system enables the integration of dynamic geospatial data and allows users to interact directly with the map.

By using Leaflet, the plugin supports key functionalities such as displaying user-submitted data, overlaying layers, and providing interactive tools like zoom, search, and custom markers. This approach ensures a seamless and intuitive experience, while maintaining flexibility for further customization and expansion.

Among the core functionalities established for the plugin and directly linked to cartography are data download, address search, and the ability to add layers, temporarily by users and permanently by the administrator.

To manage the data-download feature, a functionality has been developed that allows the administrator to enable or disable this option as needed. When activated, a button is displayed on the map interface. Upon clicking the button, a GeoJSON file is generated based on the data approved by the administrator and stored in the database. This functionality enhances the reusability of the generated information, allowing it to be integrated into other tools, such as Geographic Information Systems (GIS).

This feature ensures that the plugin not only facilitates dynamic data interaction but also supports interoperability with external platforms, further extending its application and utility.

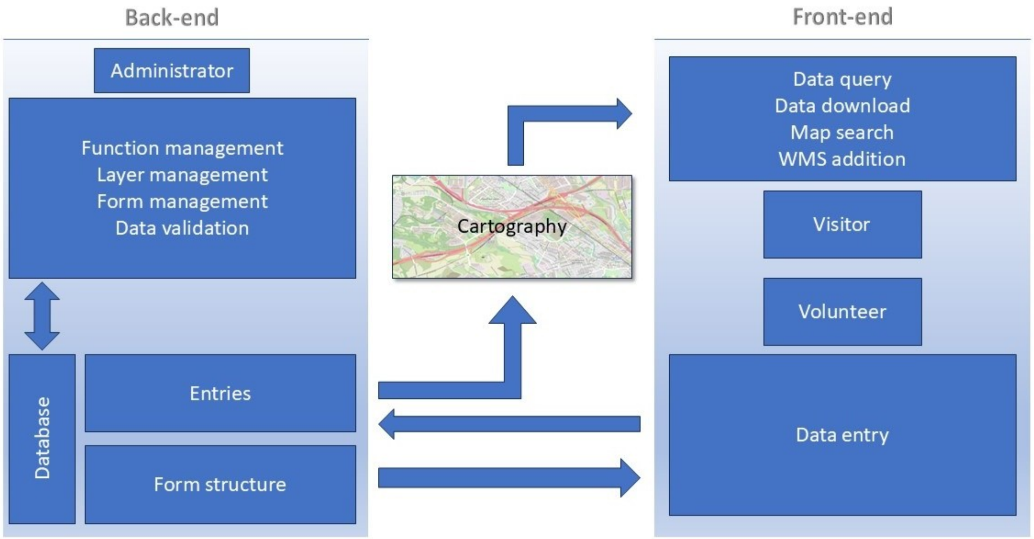

Figure 3. Operational Structure of NexusMap
Source: Authors' own elaboration

The implementation of this functionality required designing a data structure that ensured both the flexibility and reliability of the system. To achieve this, an independent JSON file was created for each form submitted. This JSON file is invoked when rendering the form on the front-end, allowing the system to dynamically construct its structure.

When a user completes the form, the submitted information is stored as a JSON object (serialized by PHP with the serialize function) in the entries table. This approach provides several advantages: flexibility (the system can handle diverse form structures without requiring schema modifications in the database); efficiency (storing the data as JSON allows for compact storage and easy retrieval) and scalability (the dynamic nature of the structure supports the addition of new forms and fields without disrupting existing functionality). This method ensures that the system remains adaptable to different project requirements while maintaining robust data integrity.

The function that generates the GeoJSON file for download processes each JSON object stored in the entries table, adapting them to a standard format recognized by the OGC (Open Geospatial Consortium, 2020). To meet the minimum requirements of the GeoJSON standard, the file must include a basic structure specifying the following: object Type (the type of GeoJSON object, such as FeatureCollection or Feature); geometry (the spatial representation of the data. Currently, this is limited to Point geometry, but the system has been designed to accommodate additional types in the future, including LineString, Polygon, MultiPoint, MultiLineString, and MultiPolygon) and properties (the attributes associated with each object, which provide descriptive information about the spatial data).

This implementation ensures compliance with the GeoJSON specification while maintaining flexibility to expand functionality as needed. The GeoJSON file enables seamless integration with other geospatial tools and platforms, ensuring interoperability and enhancing the utility of the plugin.

For the address search and zoom functionality, the Leaflet Control Geocoder library (Liedman, n.d.) was utilized. This library enables the integration of a search field on the map, allowing users to input an address and, upon locating the result, automatically zoom to the specified location. Additionally, a feature has been implemented to give administrators the ability to enable or disable this functionality as desired. This flexibility ensures that the search and zoom capabilities can be tailored to the specific needs of each project, enhancing usability without imposing unnecessary features.

For the layer incorporation functionality, it is necessary to distinguish between the administrator and the end user. The end user has access to a panel that allows them to add WMS (Web Map Service) layers of their choice to the map. This feature has been implemented using a simple function that adds the WMS layer to an array, which is then read and rendered by Leaflet. Regarding the administrator's options, both base layers and overlays added to the map are stored in WordPress's options table, ensuring data persistence and accessibility. Additionally, a fallback function has been implemented to load OpenStreetMap as the base map if the system does not detect any layers defined by the administrator.

The administrator also has access to features for creating forms and validating submissions. For form creation, a comprehensive management system has been developed using a Drag & Drop interface, providing intuitive and visual experience for structuring content. Administrators can add a variety of fields, including titles, text fields, checkboxes, radio buttons, dropdown menus, as well as more advanced fields like file uploads and date selectors. Additionally, fields can be reordered by dragging the elements, offering greater flexibility in form design. Since the plugin is designed for collaborative mapping, map functionality is implemented by default, making it mandatory to include geographic data in all forms.

As an additional feature, the plugin supports the creation of A/B forms, or conditional forms, based on the selection of the end-user type. This allows the administrator to offer two different form options tailored to specific user categories, enhancing the flexibility and adaptability of the system.

Finally, a validation functionality has been implemented to manage the forms submitted by users. Upon form submission, the system utilizes WordPress's native wp_mail() function, which is part of its core. This function simplifies email delivery by leveraging the hosting server's configuration, eliminating the need for complex adjustments, to notify the administrator via email.

The administrator, through the plugin's control panel, can review the submitted data, evaluate it, and either approve or reject it as appropriate. This functionality was developed to meet the validation and moderation requirements outlined in the initial objectives of this section.

4. 4. Testing and Evaluation

To ensure the quality, stability, and proper functioning of the NexusMap plugin, an exhaustive set of tests and evaluations was designed and executed, focusing on both functional aspects and system usability. These tests were conducted at various stages of development to identify potential errors or inconsistencies in the plugin's behaviour and to ensure that its functionalities met the established requirements effectively.

4.4.1. Functional testing

Functional testing was conducted to ensure that all plugin features operated correctly across various environments and configurations. These tests included the following aspects:

First, compatibility with different WordPress versions was verified. The plugin's performance was tested on multiple WordPress versions, ensuring its functionality on both recent and older releases. Additionally, the plugin was evaluated across various browsers and devices, including Chrome, Firefox, Safari, and Edge, as well as mobile phones and tablets. The results confirmed a responsive front-end design, which works seamlessly across all screen sizes, while the administrator interface was specifically optimized for desktop use due to its complexity.

Key functionalities, such as form creation and management, map visualization and interaction, data download, and communication with the database, were thoroughly tested. Integration with other plugins and themes was also examined to ensure that NexusMap did not cause conflicts with commonly used WordPress plugins. Although it is impractical to test compatibility with all existing plugins, some issues were observed with caching plugins, which delayed updates made by the administrator, particularly for data stored in the wp_options table. As it is generally inadvisable to disable caching functionality, and to avoid conflicts with other plugins, a notification system was implemented to inform users about the potential delays caused by these plugins.

4.4.2. Usability testing

Although usability testing was conducted internally by the developer, objective methodologies were employed to evaluate the user experience effectively.

The interface was assessed using a heuristic analysis based on recognized usability principles, such as consistency, immediate feedback, and reducing cognitive load for users. Simulations of various usage scenarios were also conducted to replicate typical workflows and interactions with the plugin, identifying potential areas of confusion or features that could be improved.

Navigation optimization was a key focus, with adjustments made to the organization of menus and options to facilitate access to frequently used features and reduce the time required to complete common tasks. Additionally, the graphical interface was refined to ensure that visual elements were intuitive and that information was presented clearly and concisely.

These tests highlighted several areas for improvement in the interface and overall interaction with the plugin, resulting in a smoother and more satisfying user experience.

5. Results

The NexusMap plugin is available for download from its official GitHub repository (https://github.com/EscalaDigital/nexusmap). The main outcomes of its development are presented by functional area. The section first introduces the core modules (Form Builder, entry management, map configuration, and layer control) along with their design principles. It then explains how maps and forms can be embedded using shortcodes. Finally, it summarizes the findings of a structured usability evaluation conducted with undergraduate and graduate students, highlighting the plugin's performance, ease of learning, and areas identified for future improvement. Once installed and activated, the NexusMap plugin is accessible through the sidebar menu in the WordPress admin panel. From this menu, users can navigate to several main sections, each dedicated to a specific aspect of the plugin's configuration and usage.

Form Builder: The main section of the plugin, Form Builder, allows users to create and customize forms by dragging and dropping elements. This tool includes a left-hand panel containing a list of draggable fields. Among the basic fields available (Figure 4) are titles, text fields, text areas, checkboxes, radio buttons (radio groups), dropdown menus, file uploads, numeric fields, date selectors, and URL fields. Additionally, each field added to the construction area can be customized, including its label, name, and specific options, depending on the field type. The section also includes functionality for removing fields, ensuring flexibility and ease of use during form design.

The Form Builder also provides the option to enable A/B testing through a specific checkbox. Users can define custom names for the A and B options and save them using a corresponding button, which activates the functionality to create two distinct forms. This feature allows administrators to design conditional workflows tailored to different user groups or scenarios.

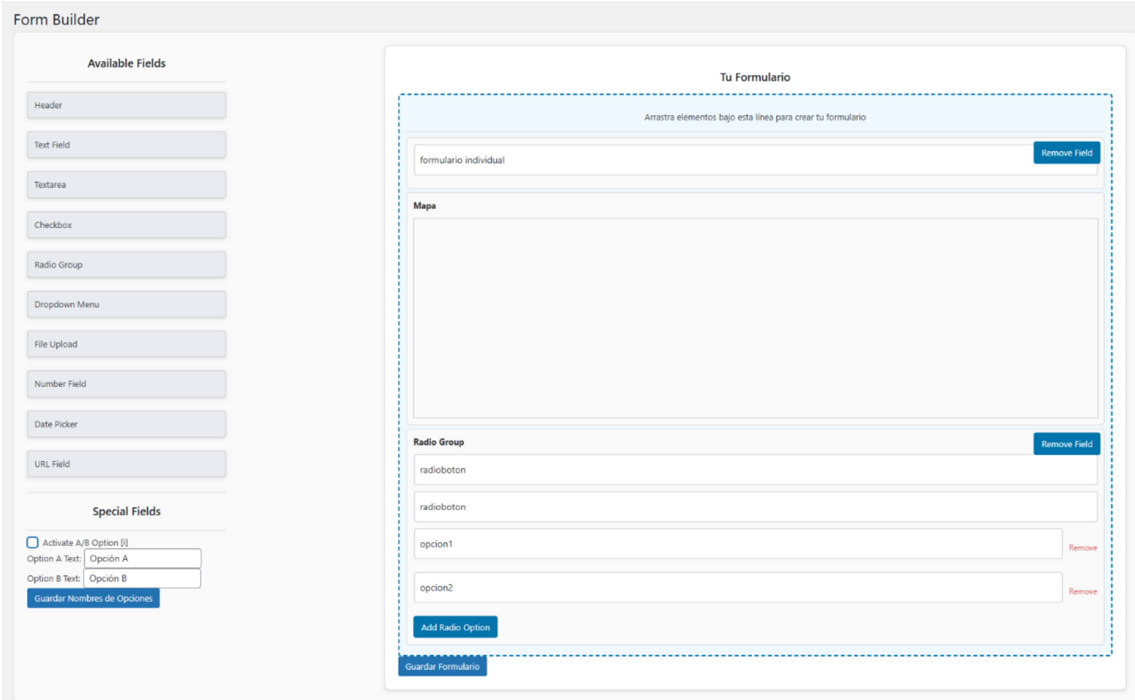

Figure 4. Custom Form Creation Interface Using Drag-and-Drop
Source: Authors' own elaboration

Entries (Record Management): The Entries section provides a tabular view of all submissions made through the forms created with NexusMap. The table includes columns displaying the following information: Record ID (a unique identifier for each submission); Submission Date (the date and time the entry was submitted); Status (indicates whether the entry is pending, approved, or rejected); Available Actions (includes options to view details and Approve or Reject Entries).

This section provides an organized and efficient way to manage user-submitted data, ensuring that the information displayed on the map meets the desired quality standards.

Map Settings: In this section (Figure 5), users can configure general map options, such as enabling or disabling data download in GeoJSON format, activating the search functionality within the map, and allowing the addition of custom WMS layers. Additionally, users can adjust the default map visualization settings and configure interaction options to enhance the user experience.

Layers Management: This section is divided into two main subsections: Base Layers and Overlay Layers (Figure 5).

For Base Layers, users can add new layers by providing a name, the URL of the tile layer, and the corresponding attribution. Existing base layers can also be managed in this subsection, with the option to delete them if necessary. For Overlay Layers, the form allows users to specify the layer name, type (GeoJSON or WMS), URL, and, in the case of WMS layers, the specific layer name. Like base layers, existing overlay layers can be managed directly within this subsection, offering options for modification or removal.

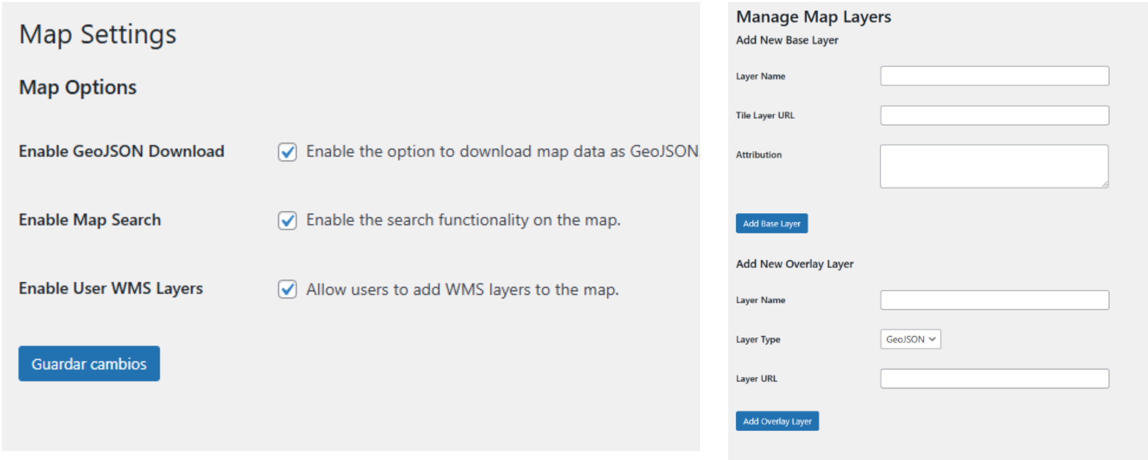

Figure 5. NexusMap Plugin Management and Configuration Interfaces
Source: Authors' own elaboration

To utilize the elements created within the website's front-end, the plugin also allows the insertion of maps and forms directly into pages or posts using shortcodes. In WordPress, a shortcode is a snippet of code enclosed in square brackets that enables the inclusion of dynamic content or functionality without requiring programming knowledge.

To insert a map (Figure 6), the following shortcode can be used:

[nm_map lat="0" lng="0" zoom="2" width="100 %" height="400px"]

This shortcode embeds an interactive map into the specified page or post, allowing the configuration of latitude (lat), longitude (lng), zoom level (zoom), and map dimensions (width and height). To insert a form, the following shortcode is used:

[nm_form]

This shortcode embeds the form created in the Form Builder, enabling user information to be collected directly from the website. The form is displayed only if the user is logged in; otherwise, a notification is shown prompting them to log in. This approach ensures that the data submitted is linked to a specific user, maintaining accountability and data integrity.

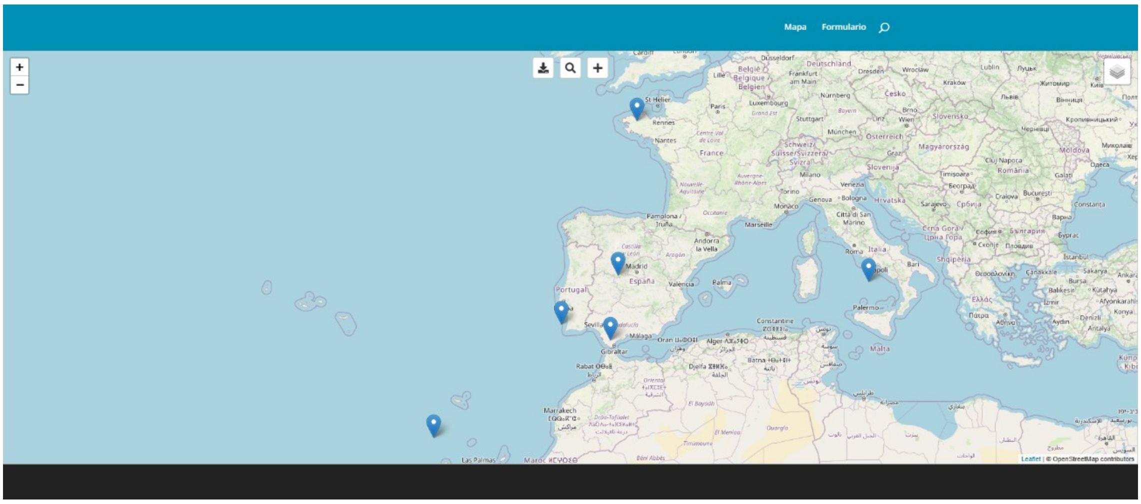

Figure 6. Example Cartographic Representation with NexusMap
Source: Authors' own elaboration

In order to assess the usability and effectiveness of the developed plugin, a series of sessions were conducted in two courses at the University of Seville during the first and second terms of the 2024/25 academic year, coinciding with the final stages of the plugin's development. After the completion of these sessions, several surveys were carried out, including both qualitative and quantitative questions. The purpose of these questions was to evaluate students' perceptions regarding various aspects of the plugin, such as ease of use, learning curve, the value of its functionalities, and its limitations.

The evaluation was carried out in two different courses:

- Territorial Information Technology Applied to Destinations, a fourth-year course in the Tourism Degree at the University of Seville, with 15 enrolled students, none of whom had prior experience with Geographic Information Systems (GIS). Collaborative mapping is used to tourism planning and management, enabling real-time geospatial data collection and infrastructure optimization. Since students have no prior experience with GIS, the plugin will provide an intuitive introduction to geospatial tools.

- Development Cooperation: Financing, Actors, and Internationalization, a (Master's in Territorial Management) course, with 10 enrolled students who had more extensive experience in the use of GIS. Collaborative mapping is crucial for project planning and evaluation in development cooperation, particularly in regions with limited access to official geographic data. Students with more GIS experience assessed the plugin's interoperability and applicability in development contexts.

In the undergraduate course, students were introduced to the principles of collaborative mapping, as well as the use and installation of WordPress. Subsequently, they used NexusMap to create and share spatial information. The plugin was compared with other commonly used platforms for collaborative mapping, such as Google My Maps and Ushahidi.

In the master's course, in addition to providing the basic knowledge required to manage WordPress, the focus was on using NexusMap for studies related to development cooperation projects, evaluating its potential to visualize and analyze spatial data.

A survey was conducted among the students. The questions were answered using a 5-point Likert scale (1 = Strongly disagree, 5 = Strongly agree). The survey results are presented in Table 3.

The analysis of the responses reveals differences in the perception of NexusMap depending on the level of prior experience with cartographic tools.

In general, students without GIS experience rated the tool more positively, highlighting its ease of use and integration with WordPress. In contrast, students with prior GIS knowledge were more critical of certain aspects, such as user-friendliness compared to more advanced tools and efficiency in team-based tasks.

Students without prior experience found NexusMap to be an accessible and useful tool for their projects, with a reasonable learning curve. The intuitive interface and the flexibility to customize forms were especially appreciated. However, some mentioned that the documentation could be more detailed to facilitate initial understanding. On the other hand, students with GIS experience indicated that, while NexusMap is a functional tool, in some respects it was too basic compared to more advanced solutions such as QGIS or ArcGIS. The lower score regarding teamwork capabilities suggests that improvements should be implemented, including adding of features that enable better collaboration.

Table 3. Survey Results

Statement	Average (no GIS experience) n 10	Average (GIS experience) n 15
The installation and configuration of NexusMap were straightforward and free of technical difficulties.	4.5	4.1
The NexusMap interface is clear and intuitive for creating and editing collaborative maps.	4.6	4.4
exusMap facilitates the integration of spatial data into research projects.	4.7	4.5
Compared to Google My Maps and Ushahidi, NexusMap offers greater flexibility for customizing forms.	4.5	4.3
I believe that NexusMap allows for better data management in collaborative projects compared to other tools.	4.3	4.1
Integration with WordPress facilitates the online publication of the created maps.	4.8	4.6
The data export capabilities of NexusMap are useful and compatible with other GIS platforms.	4.4	4.2
The available documentation was sufficient to learn how to use the tool without difficulty.	4.2	4.0
I found NexusMap to be more user-friendly compared to more traditional GIS tools.	4.0	3.5
I believe that NexusMap has the potential to be used in contexts of research, cooperation, territorial planning, and/or tourism.	4.9	4.7
I would recommend NexusMap for collaborative mapping projects.	4.7	4.5
I would like to continue using NexusMap in the future for managing collaborative mapping projects.	4.8	4.6
The use of NexusMap is efficient for teamwork.	4.0	3.8

Source: own elaboration.

In addition, three open-ended questions were included to gather qualitative feedback:

1. What were the main challenges or difficulties you faced when using NexusMap compared to other tools?

2. What features or improvements would you add to NexusMap to optimize its use in collaborative projects?

3. In what types of projects or applications do you think NexusMap could be utilized?

Students without GIS experience mentioned that the main difficulty was becoming familiar with the WordPress system, while students with experience highlighted that improving interoperability with other GIS tools, for instance, by allowing the creation of WMS or WFS services, is a key area for improvement. Additionally, the following enhancements were suggested:

• Greater compatibility with advanced GIS tools: Improved integration with QGIS and ArcGIS, enabling greater data interoperability.

• Statistics capabilities: Adding features that allow users to select fields for displaying data summary statistics.

• Search filters: Students appreciated the ability to search for locations on the map but emphasized the need for data-based filtering options.

• Performance optimization: Reduction of loading times and improved management of layers with large volumes of data.

In addition to all the previous proposals, students suggested several specific potentials uses for NexusMap in urban planning, sustainable tourism, environmental monitoring, and development cooperation. Its utility was also identified for collecting spatial data in academic research and managing participatory projects at the local level.

6. Discussion

This study represents a significant advancement in identifying the scientific and technical requirements that collaborative mapping tools must meet to be effective across diverse application contexts. It highlights the importance of developing a solution that not only facilitates data collection but also provides an accessible, adaptable, and scalable environment for projects of varying scope and specific functionalities.

The modular and flexible architecture of NexusMap, built on WordPress, constitutes a substantial contribution in this regard. WordPress, used by more than 40% of websites worldwide (Kinsta n.d.), offers an accessible framework for both users and developers, enabling the integration of advanced functionalities such as interactive map visualization and geospatial data management. These features are fundamental for Volunteered Geographic Information (VGI) projects (Goodchild 2007). Furthermore, using WordPress as a foundation introduced additional challenges because its structure does not strictly follow Model-View-Controller patterns, requiring creative solutions to ensure efficient integration. This approach reinforces the claims of Brovelli et al. (2016), who emphasized the need for flexible and open VGI tools to maximize their impact in various contexts.

The emphasis on open-source software strengthens the project's sustainability, aligning with previous studies that highlight how open-source tools foster long-term collaboration and innovation (Fressoli & Smith 2024, Sun *et al.* 2024). In addition, the user and developer communities have the potential to contribute to the plugin's improvement and expansion, ensuring its relevance in response to evolving geospatial challenges. NexusMap has also moved beyond the development phase and is currently in active use in real-world settings, under the authors supervision. Specifically, the plugin forms a central component of the first author’s doctoral dissertation and is being applied in several competitive research projects. Its implementation in real contexts provides continuous feedback on usability, performance, and desired improvements, which is systematically integrated into a structured maintenance roadmap. At the same time, this hands-on approach drives the gradual introduction of new functionalities, ensuring that the plugin evolves in alignment with user needs and technological advancements.

The development of NexusMap required overcoming challenges related to the implementation of key functionalities, including the integration of dynamic maps using the Leaflet.js library and data management through GeoJSON. These features have proven critical for collaborative mapping projects, where interoperability and ease of use are essential (Pedregal *et al.* 2024; Open Geospatial Consortium, 2020).

Despite the progress made, there remain clear opportunities for improvement and expansion that could significantly enhance NexusMap's utility and adaptability across a broader range of application contexts. In particular:

- Support for multiple geometry types: Beyond points, the ability to draw and store LineString and Polygon geometries (and their multi-variants) would unlock advanced use cases, such as delineating walking or cycling routes, defining service-area boundaries, or mapping land-use parcels, crucial for urban planning, infrastructure management, and environmental monitoring (Brovelli et a*l.* 2016).
- Advanced filtering and descriptive statistics: Implementing attribute- and date-based filters, combined with on-the-fly statistical summaries (e.g. frequency counts, histograms, heatmaps), would empower users to explore patterns in the volunteered data directly within the interface, reducing reliance on external GIS tools (Heipke 2010).
- Automated analysis using artificial intelligence: Integrating machine-learning models could provide real-time quality control (detecting topological or semantic anomalies), sentiment analysis of user comments, and spatial clustering to highlight emerging hotspots of activity or concern.
- Collaborative validation and communication: Introducing voting mechanisms, threaded comments on existing geometries, and real-time notifications would foster collective review, increase data credibility, and encourage sustained engagement, features common in Participatory GIS (Foody *et al.* 2013).
- Dynamic OGC service generation: Allowing validated datasets to be published as on-demand WMS/WFS layers would simplify downstream integration into desktop GIS and institutional platforms, promoting interoperability (Open Geospatial Consortium, 2020).
- Internationalization and localization: Leveraging WordPress's native translation API to enable multilingual interfaces and localized content would broaden NexusMap's accessibility for a global user base.
- Community support and extensibility: Establishing an online hub for plugin users and developers, complete with documentation, issue tracking, and extension templates, would reflect best practices in open source (Raymond 2001) and ensure NexusMap's evolution in line with emerging geospatial challenges.
- Performance, offline use, and ease of deployment: Optimizing map rendering for large datasets, adding offline caching for mobile surveys, and providing Docker-based installation scripts would lower technical barriers and improve user experience across diverse devices.
- Evaluation: The evaluation conducted with undergraduate and graduate students offers valuable insights into NexusMap's usability and learning curve; however, it should be noted that these tests were performed in controlled academic settings and do not fully replicate the complexity of real-world participatory mapping projects. While these classroom trials validate core interface and workflow aspects, they should be interpreted as preliminary usability assessments rather than comprehensive validations of the plugin's effectiveness in diverse field environments.

Despite these potential improvements, in its current state, NexusMap addresses the fundamental needs of collaborative mapping projects, providing a functional solution that enables projects that were previously constrained by a lack of suitable tools or budget limitations. Overall, NexusMap has been well received by both students with and without GIS experience, showing a strong intention for future use and recommendation in collaborative mapping projects. However, the analysis reveals that advanced users seek improvements in interoperability and teamwork functionalities, suggesting that future updates of the plugin could prioritize a focus on these aspects to enhance its adoption in more demanding professional environments.

7. Conclusions

This study introduces a tool for generating collaborative cartography, designed to democratize access to geospatial data creation by enabling both technical and non-technical users to actively participate in cartographic projects. The proposed tool addresses these needs through a modular and accessible design, ensuring its usability for both technically trained users and those with no prior programming experience. Built on open-source software, the tool enhances its potential by allowing users to adapt and customize the system according to their specific requirements. This feature ensures long-term sustainability and adaptability to emerging demands and technological challenges. NexusMap represents a significant advancement in developing accessible and functional tools for collaborative cartography, removing technical and economic barriers that previously hindered adoption in projects with limited resources.

Although areas for improvement have been identified that could further expand NexusMap's capabilities, the tool meets its proposed objectives. In addition to bridging the gap between collaborative data and institutional standards, it lays the groundwork for the future development of collaborative mapping tools. Its focus on accessibility, sustainability, and adaptability positions it as an optimal and versatile solution for projects aiming to address citizen participation studies.

8. Acknowledgements

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