A Web Platform for Virtual Interpretive Water Trails

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Abstract: The Universidad Veracruzana (UV), through its Sustainability Coordination (Cosustenta), promotes awareness about environment protection and water resources by means of interpretive trails. To support this activity, a research group developed a software platform to manage all the digital resources needed to offer this educational online tool. The goal is to extend environmental education to people who for several reasons cannot participate in an in-situ visit. As a first step, the material of several environmental organizations that offer online educational resources was reviewed in order to analyze the interfaces, services and resources that they provide, including images, videos, audio files, among others. SCRUM was selected as the agile software development methodology, and open-source software such as PostgreSQL, XAMPP, PHP, HTML, CSS, GitHub, Bootstrap, was used. A relational database was designed to manage data from a web server with internet access. This database can host multiple interpretive trails with specific data and multimedia resources. The software uses educational material designed by Cosustenta for the Health Sciences Unit in Xalapa, Veracruz to show how it works; it also uses resources in several formats to enrich the user experience at each stop along the trail. The result is a web application called SENDINA, which promotes environmental education by integrating technology with sustainability.

Keywords: environmental education, interpretative trails, multimedia platform, sustainability

Introduction

Climate change, biodiversity loss, and environmental pollution represent urgent challenges for the planet and humanity, which are addressed by Environmental Engineering through the planning and execution of technical projects as well of the design of educational strategies to generate changes in people's perception and behavior. In this context, educational trails constitute valuable scenarios for developing environmental awareness among the population and an excellent tool, based on socio-environmental communication, to promote sustainable behavior models (Environmental Education Lanzarote, 2025).

An interpretive trail (also known as an educational, pedagogical, or instructional trail) is a planned route within a natural or semi-natural space that includes informational or interactive stations. These stations address environmental, scientific, cultural, or technical topics and allow visitors to observe, reflect, and learn while walking through the area. Its main objective is to educate visitors about the value of natural resources, local environmental problems, and possible solutions, many of which are directly related to Environmental Engineering (Rumbonaturaleza, 2022).

Environmental Engineering focuses on developing technical solutions for problems such as water management, waste treatment, and remediation of contaminated soils. However, educational support must also be developed to promote public participation. Environmental education should not be limited to classroom instruction or passive information campaigns; it needs to engage people emotionally and cognitively so they can directly experience and understand the importance of the natural environment. Educational trails fulfill this function by offering a learning experience through direct contact with ecosystems (Knowledge Hub, 2023).

Educational institutions play a crucial role in building more just, equitable, and sustainable societies through their teaching, research, and outreach functions. Universities, specifically, train future professionals who will participate in the political, social, and economic life of society. Universidad Veracruzana recognizes this and has been committed since 2010 to developing institutional policies that incorporate a sustainability perspective into teaching, research, outreach, and management functions. This commitment is demonstrated through the University Coordination for Sustainability (Cosustenta UV) (Cosustenta, 2025), which has implemented interpretive water trails accessible to both members of its academic community and the public, to awareness about the importance of water resource conservation.

This paper presents a proposal for a web application that offers the opportunity to explore water-related interpretive trails to the public, who for several reasons cannot physically visit them. This tool expands access to environmental education and raises awareness within society. An online platform allows users to enjoy a virtual experience where they can explore, learn, and understand the importance of natural resource conservation from any internet-connected device at any time, without the need to physically visit the location.

SENDINA (Interpretive Trails of Water) is a web application that provides a preliminary overview of the Interpretive Trail of Water at Health Sciences Unit of Universidad Veracruzana in the city of Xalapa. It contains relevant information for each station along the trail, displaying photographs, videos, and other multimedia materials through virtual panels (Lucho, 2024).

SENDINA allows the creation of interpretative trails with their respective stations and multimedia materials, not only for the Xalapa Region but for any of the five zones of the Universidad Veracruzana, for which the system was originally designed. The software application has a flexible structure, and can manage multiple trails, each with several stations, each containing different types of educational material (Lucho, 2024).

Materials and Methods

This section describes the methodological framework used to analyze existing interpretative trails and to design and implement the proposed web platform.

Virtual Trails

Interpretive trails are present around the world and have increased in number due to the growing interest of organizations in environmental sustainability. However, during the Covid-19 pandemic many interpretive trails were temporally closed to protect public health, which boosted the development and implementation of online tools. These platforms give people the ability to interact with and learn from trails without leaving home, by incorporating digital visualization and multimedia resources to offer users interactive learning experiences without the need for physical travel (Lucho, 2024).

Some examples of interpretive trails that embraced digital transformation and became not only physical but also virtual experiences are presented.

Red Front Trail

This is a remarkable example of natural resource management focused on ecosystem conservation and habitat protection. It also hosts the Yale School of the Environment, dedicated to postgraduate training in forestry management. The trail is in Montana, United States, with a 1.5 km route that runs through a section of extensive Yale-Myers forest (Figure 1). The path comprises 14 stations that address themes related to forest health, wildlife habitat conservation and native species diversity (Yale Forests, 2024a).

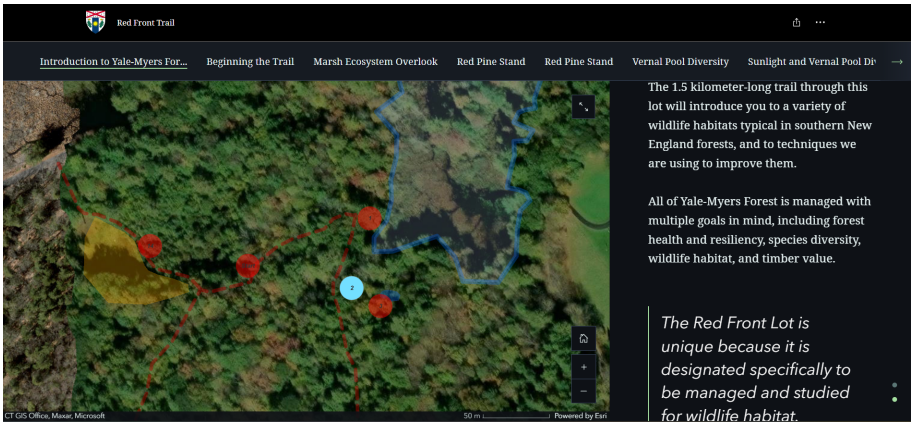

Figura 1. Módulo fotovoltaico de 40 celdas conformado por 4 strings

On May 4, 2020, the Office of School Forests launched an online platform called “Story Map," which allows users to virtually explore the trail. This platform is full of photos and descriptions of wildlife habitat along the trail, which reflects

countless contributions to trail construction, writing, research, and design over the years from staff, students, and faculty (Yale Forests, 2024b).

Newcomb Naturalis

The College of Environmental Science and Forestry of State University of New York State have several interpretive trails where thousands of visitors and local residents participate in educational programs within Adirondack Park, an unique natural, cultural, and recreational resource in New York. These trails include the R.W. Sage Jr. Memorial Trail, Rich Lake Trail, Peninsula Trail, and Sucker Brook Trail. They address several topics related to coniferous forests, Rich Lake, and the ecosystems of this region (State University of New York College of Environmental Science and Forestry [ESF], 2024).

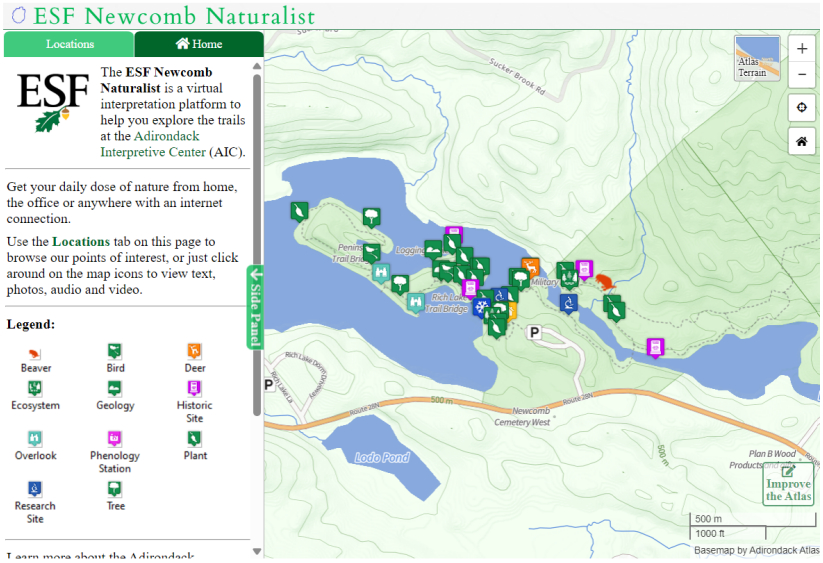

Figure 2. Newcomb Naturalis Map

Despite the simplicity of the platform (Figure 2), it displays all points of interest along each trail and provides brief information about each station.

Rain Garden interpretative Trail

This trail is located in the suburbs of the Rain Garden in West Torrens, South Australia. The trail map (Figure 3) shows stations focused on rainwater harvesting and collection from rooftops, roads, and paths. It contains ten stations, and therefore the trail can be explored on foot or by bicycle (Westtorrens, 2023).

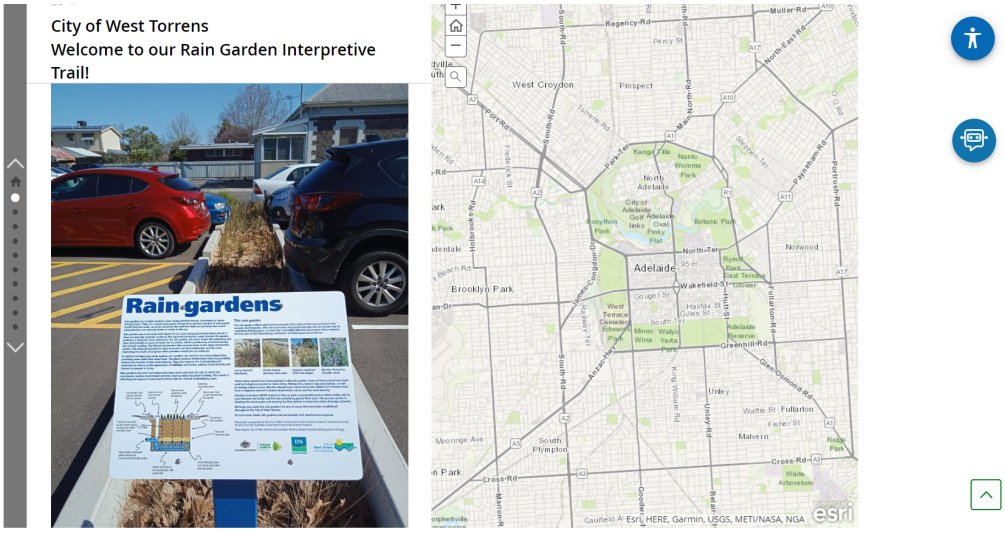

Figure 3. Rain Garden interpretive trail

In Mexico, there are several interpretive trails focused on sustainability and environmental awareness; however, few of them have digital platforms that allow virtual exploration . This represents a significant opportunity for people unable to travel and visit these trails personally. Therefore, it is important to highlight the relevance of virtual format for Universidad Veracruzana interpretive water trails, because as it can broaden acces and facilitate environmental education for a larger audience.

Universidad Veracruzana Trails

In 2018, the University Center for Arts, Sciences, and Culture, Córdoba (CUACC), became the first center with an interpretive trail called "Saturday with Nature." This trail allows people to learn about several topics and to participate in many outdoor activities focused on sustainable living. Some of topics covered on this trail are: 1) Carbon Cycle; 2) Water Cycle; 3) Archaeological History; and 4) A garden of medicinal, culinary, and aromatic plants (Universidad Veracruzana [UV], 2024).

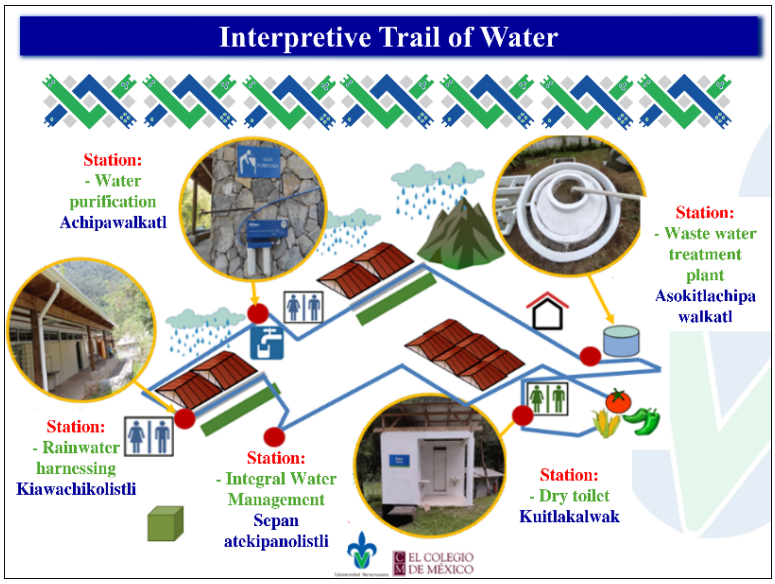

Figure 4. SIA stations

In 2022, a second trail was implemented, with a Nahuatl name "Tehwan ti ameh" (Figure 4), or "Interpretive Trail of Water (SIA)". Students from Environmental Engineering, Architecture, and Intercultural Management for Development, careers at Universidad Veracruzana (UV) in Orizaba-Córdoba region and El Colegio de México participated in this development (UV, 2023). This trail was based at the Universidad Veracruzana Intercultural (UVI), Grandes Montañas campus, with a purpose: to address, with local communities in Zongolica region, the significant challenge to water access and its comprehensive and sustainable management (Figure 4).

The trail consists of eight educational stations within the UVI facilities, accessible through a 90-minute guided tour offered in both Spanish and Nahuatl. This stations invite visitors to reflect on: 1) The relationship between humans, water, and climate change; 2) rainwater harnessing, 3) water purification, 4) wastewater management, 5) a wastewater treatment plant, 6) wetlands; 7) dry toilet and 8) composting (UV, 2024).

In 2023, in the "Cells for Sustainability" project, Interpretive Trail of Water was created for Health Sciences Unit–Xalapa (UCS-X) with the purpose of creating awareness in university community and society about sustainability issues related to the integrated management of water resources (Figure 5). This project is directed to university community: students, teachers, administrative staff, and users of medical services offered by UCS-X. The Interpretive Trail of Water represents an educational opportunity specifically about relationship between water and users as well as influence on health. According to the type of UCS-X visitors, the trail can be visited with a guide or by themselves. The UCS-X Interpretive Trail of Water contains eight educational stations: 1) Map of Interpretive Trail of Water at UCS-X; 2) People, Water, and Health; 3) Water and Green Areas; 4) Rainwater harnessing and storage; 5) Water treatment; 6) Waste water; 7) Water and energy, and finally 8) Water and science (UV, 2024).

Figure 5. UCS-X Trail Launching

Scrum

Scrum is a framework for agile software development thath has been extended to other areas, as it provides a set of best practices for collaborative teams to achieve optimal results in project development (Agile Projects, n.d.). This methodology helps organize teams, enabling them to learn from experience and adapt to change; it is particularly useful in software development for solving complex problems in an efficient and sustainably manner (Amazon Web Services [AWS], 2024). It consists of different stages, as illustrated in Figure 6 (Synapptica, 2025).

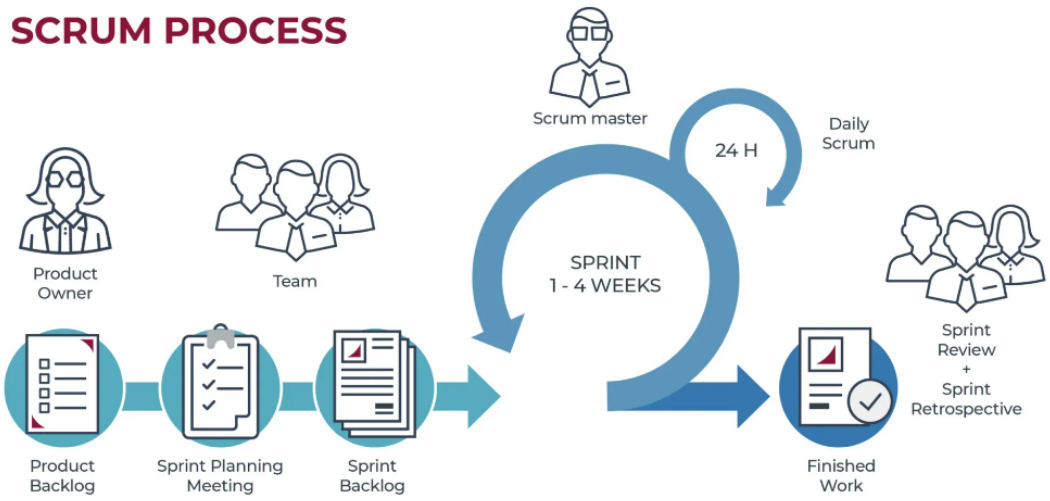

Figure 6. SCRUM model stages

Development Software

Figure 7 presents the software tools used to develop the web application, along whit a brief description of each component.

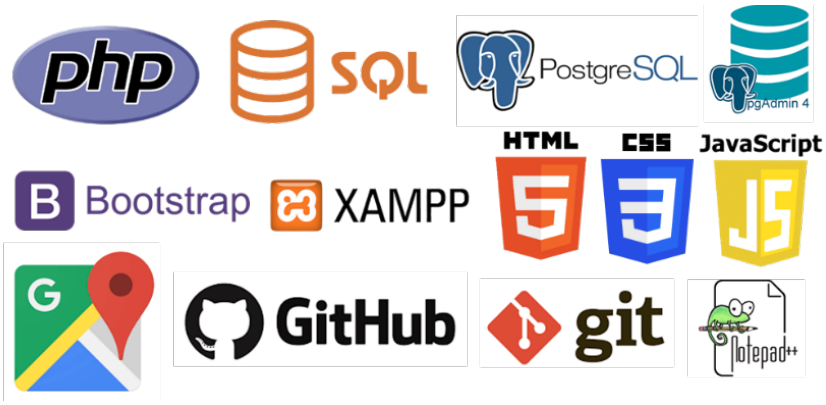

Figure 7. Software tools used in web application development

A relational database model was implemented using PostgreSQL version 15.2,selected for its robustness and ease of use. For database design, administration, and querying, pgAdmin4 was selected. This integrated tool provides a graphical interface for database management and it is used along with XAMPP, a free and open-source platform for local web application development,enabling both database management and web server operation. Notepad++, a text editor supporting multiple programming languages and plugin integration was also used (Lucho, 2024). The backend was developed using PHP (Hypertext Preprocessor), an open-source scripting language designed for dynamic web applications; where code execution occurs on the server prior to being sent to the client's browser. For the frontend, Bootstrap, a free and open-source framework, was used in combination with HTML (HyperText Markup Language) and CSS (Cascading Style Sheets), to define the visual appearance of web interface, including layout, colors, and typography (Lucho, 2024). The Google Maps API (Application Programming Interface) was integrated to display the geographical location of each station along the trail, while JavaScript was used to implement interactive elements and animations (Google, 2025).

The project was developed using GitHub, an online platform for version control and collaborative software development. Git, an open-source version control system, was used to manage code changes and facilitate collaboration among multiple users (Lucho, 2024).

According to Scrum methodology, the Product Backlog defines priority tasks and development stages,including: Requirements Analysis, Database Design, Backend Development, and Frontend Development. At each stage, user stories are definide to specifytasks, timelines, and progress tracking.

Once user requirements are identified and documented, the database design process begins (Figure 8). This includes the development of a relational model, data dictionary, and system implementation. Tables, relationships, views, and queries are designed, as well as reports requested through the interface. Finally, user interfaces to facilitate web browsing are developed, defining color palette, font styles, component layout, and logos and images to be displayed.

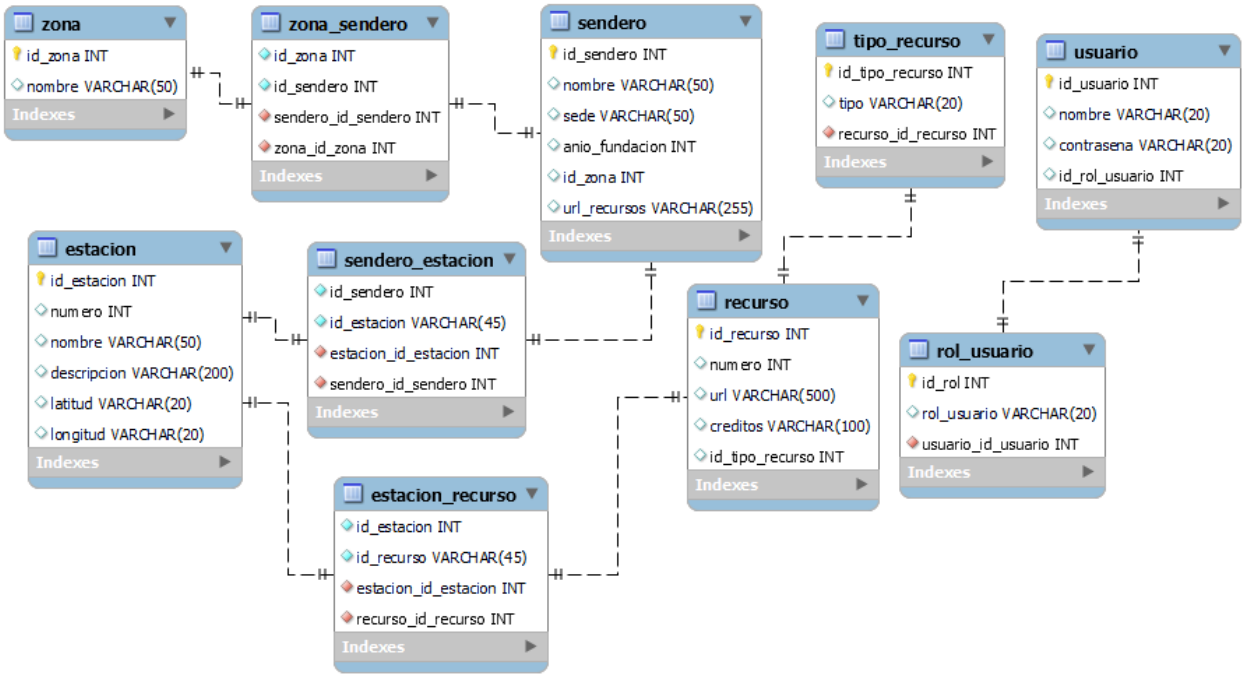

Figure 8. Relational database model

The main interface of the web application is shown in Figure 9.

Figure 9. Section of the Sendina home page

Data from the interpretive Trail of Water at the Xalapa Health Sciences Unit (UCS-X) i were used to demonstrate the functionality of the platform (Figure 10).

Researchers from the Environmental Engineering area at Cosustenta defined the components to be included, ensuring that each station displays multimedia material according to its content. Figure 11 shows the complete trail map, where users can navigate through two panels: the left panel displays multimedia content for each station, while the right panel shows the current location on the trail. A location icon indicates each station along the route, and when the cursor is placedover the symbol, the available multimedia resources are displayed.

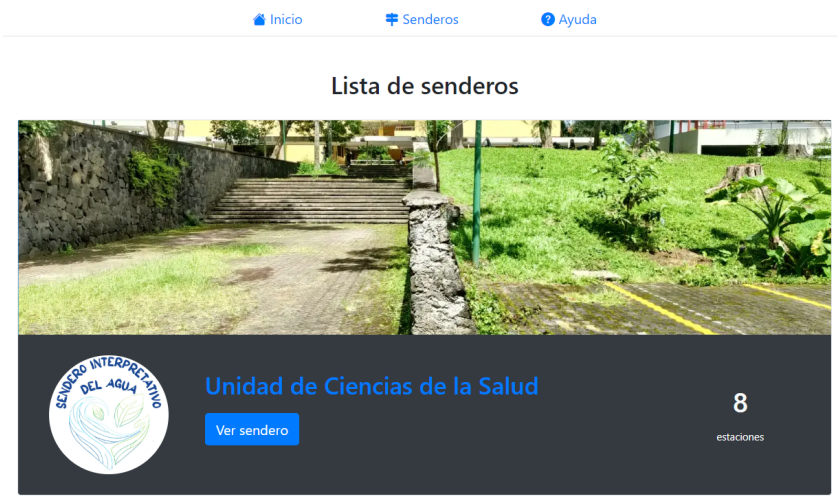

Figure 10. UCS-X interpretive trail

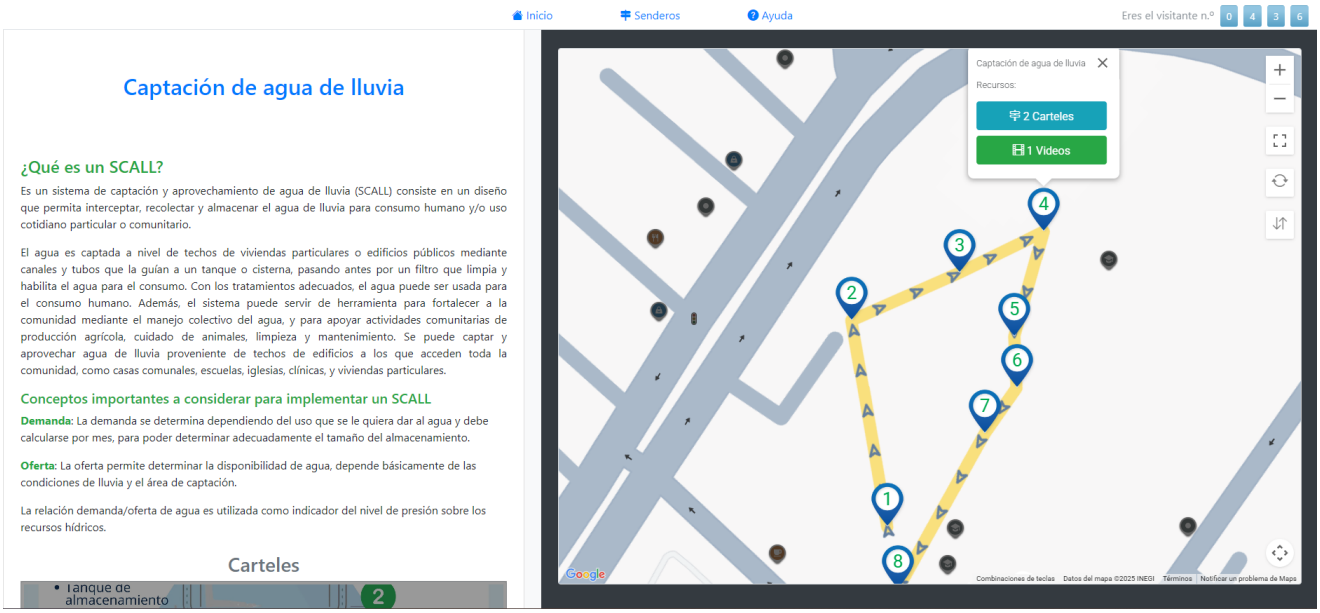

Figure 11: Section of UCS-X interpretive trail map

End users cannot modify the application or its data and are limited to browsing functionalities. The creation of new trails, including their stations and associated content, is restricted to authorized users through a dedicated management interface Only authorized and registered users are permitted to modify the platform content.

Results and Discussion

A free web application called Sendina was created and is hosted at the following URL: http://iiuv.org/Sendina/. It offers a responsive design that allows users to access and navigate its content from any electronic device with internet access. Its main objective is to manage interpretive trails created by the UV Cosustenta program, ensuring that environmental education reaches the largest audience. The platform is specifically focused on trails related to water resource conservation and initially displays the content of UCS-X Interpretive Trail of Water. This trail has eight stations located throughout the unit area, which are shown on a Google map that can be explored using the application functions, including zoom in and out, map panning, map rotation, and full-screen mode.

If users have a slow internet connection, they may experience slow loading times when displaying images on the website due to the size and quality of the multimedia resources offered. Sendina allows the inclusion of additional trails; however, the geographic coordinates of the stations and their corresponding multimedia material are required. There is no predefined limit to the number of trails that can be incorporated, nor the number of stations within each trail. As a suggestion for future improvements, additional resources that enrich the virtual experience, such as panoramic images, 360° views, or interactive environments, could be incorporated into the platform.

Conclusions

Interpretive trails, from an Environmental Engineering perspective, represent a strategic tool for promoting environmental awareness in society. These spaces allow people to connect technical knowledge with real experience, to thereby facilitating the understanding of environmental challenges and motivate the population to take care of natural resources. The integration of interpretive trails into sustainable development initiatives is fundamental for moving towards a more informed, participatory, and environmentally conscious society.

The future of the planet largely depends on collective decisions; therefore, experiential environmental education represents and effective approach to fostering responsible environmental behavior.

Among the main benefits of interpretive trails are the promotion of critical thinking, active and meaningful learning, behavioral changes towards environmental protection, and the stimulation of ecotourism and local development. The "Tehuan ti ameh" trail represents a relevant example of this educational and environmental benefits within the context of the Universidad Veracruzana initiatives.

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Author contributions: G.M.-S.: Data analysis and database design; H.-E.: Data collection, multimedia material design; L. X.-E.: Sofware design and coding; G. L.-G.: Writing and supervision.

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