

TECHNOLOGICAL SOLUTIONS FOR DIVULGATION: FINDING HUMAN AND SOCIAL PURPOSES IN ENGINEERING PROJECTS

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Abstract-- The diversity of endemic species in the state of Hidalgo reflects the great environmental diversity that characterizes Mexico; however, due to human impact on the environment, many of these species are threatened, and many more have gone extinct. This article describes the development and implementation of an interactive game designed to disseminate knowledge about the native and endemic fauna of the state of Hidalgo, contributing to quality environmental education (SDG 4) and biodiversity conservation (SDG 15). With this in mind, collaboration across society is essential; thus, engineering—through projects that may initially seem unrelated to conservation efforts—can promote environmental actions targeting a more diverse audience. The main objective of this project is to familiarize students and the general public with the species inhabiting central Mexico, fostering care and conservation. The prototype is based on a quiz format with a time-limited response challenge that increases participants' motivation and sense of reward. The game includes questions about the characteristics of eight distinct species that were selected (some of them strictly endemic and others with a wider distribution) to reinforce learning. The proposed prototype integrates electronic and logic components that allow for direct interaction with the user and is geared toward educational and science outreach settings. This proposal aims to strengthen local knowledge about biodiversity and promote various conservation actions through an innovative educational resource that is adaptable to different school and community contexts.

Keywords-- Biodiversity, Electronics, Engineering, Mathematical logic

Abstract-- The endemic diversity of animals in the state of Hidalgo is evidence of the great environmental diversity that characterizes Mexico; however, due to human impact on the environment, many of these species are endangered, and several others have become extinct. This article describes the design and implementation of an interactive game aimed at raising awareness and disseminating information about the native and endemic fauna of the state of Hidalgo. This project contributes to quality environmental education (SDG 4) and biodiversity conservation (SDG 15). With this in mind, collaboration is essential; therefore, engineering, through projects that may seem unrelated to conservation efforts, can promote environmental initiatives aimed at a broader audience. The main objective of this project is to bring students and the general public closer to the species that inhabit the central

region of Mexico, encouraging care and conservation. The prototype is based on a riddle format with a time-limited challenge, which increases motivation and rewards for participants. The game includes questions about the characteristics of eight different selected species (some of which are strictly endemic or have a wider distribution), aiming to reinforce learning. The proposed prototype integrates electronic and logical components, which allow for direct interaction with the user and are geared toward educational scenarios and scientific outreach

This proposal aims to strengthen local knowledge about biodiversity and promote specific conservation actions by utilizing an innovative and adaptable educational resource for both communities and schools.

Keywords-- Biodiversity, Electronics, Engineering, Mathematical logic

INTRODUCTION

Mexico is a country with a wide diversity of species inhabiting its territory, so much so that it is considered one of the seventeen megadiverse countries in the world. Although the state of Hidalgo is not one of the largest in terms of land area, differences in elevation, temperature, and geographic location mean that the climate and vegetation vary across the state's different regions. Each of these different climates is home to distinct species, which form part of the environment that characterizes the state.

Given the environmental crisis currently affecting Mexico and the rest of the world, unfortunately, many species are threatened or endangered, mostly due to human activities such as hunting, pollution, and the introduction of non-native species.

This project aims to raise awareness about some of the species inhabiting central Mexico, particularly in the state of Hidalgo, by creating a game based on ladder programming and logic design, in which three questions are asked about the animal's diet, appearance, and conservation status.

General Objective

To contribute to scientific outreach regarding representative species inhabiting the state of Hidalgo by developing a prototype interactive game that uses electronics, logic design, and programming to generate interest in local biodiversity among young people.

Specific Objectives

- Develop a prototype of an educational game using ladder logic programming and digital electronics, applying the operating principles of logic gates, flip-flops, and integrated circuits (Arduino Mega).
- Apply engineering knowledge and skills to a project with social impact.
- Promote the ecological diversity of the state of Hidalgo and central Mexico by teaching in an educational manner about some of the animals that inhabit the region, thereby fostering awareness and conservation of the state's wildlife.
- Propose solutions through technology and the use of accessible resources.

JUSTIFICATION

Mexico is considered one of the world's seventeen major megadiverse countries, home to between 10% and 12% of global biodiversity. This biological wealth represents an invaluable natural heritage that has begun to face growing threats due to the global environmental crisis. Although the state of Hidalgo has a considerably small land area (just 1.1% of the national territory), it exhibits remarkable bioclimatic diversity due to its complex topography, with elevations ranging from 200 to 3,300 meters above sea level. This altitudinal variability across its territory allows for a wide variety of microclimates and ecosystems that harbor diverse species. Central Mexico, particularly the state of Hidalgo, faces critical conservation challenges. According to CONABIO studies, several native species (defined as those native to the region, though not necessarily endemic) face a series of anthropogenic pressures such as habitat fragmentation, pollution, urban expansion, the introduction of invasive species, and changes in land use. This issue is part of the triple global environmental crisis recognized by the United Nations: climate change, pollution, and biodiversity loss. Within the UN Sustainable Development Goals (SDGs), this project specifically addresses SDG 15, which relates to Life on Land and focuses on halting biodiversity loss, as well as SDG 4, which is associated with Quality Education, through the creation of innovative tools for scientific outreach. The connection between these two SDGs is crucial, as the effective conservation of

Biodiversity first requires that society understand and value it. The issue of environmental education is particularly relevant. Studies conducted in the central region of the state of Hidalgo show that there is a significant gap in knowledge about local biodiversity among young people, especially in urban settings. This impact and widespread lack of awareness among the population has led to a disconnect between communities and their natural environment, which significantly hinders the development and implementation of effective conservation measures to counteract these effects. It is within this framework that science communication emerges as a fundamental strategy for addressing this ecological and educational challenge. However, the traditional methods used for outreach have a structural flaw in that they only partially capture the interest of young audiences, requiring innovative approaches that combine scientific rigor with the impact and participatory engagement of communities. The tools proposed by government agencies, which aim to improve conservation conditions and resource use, typically lack the financial or human resources to be properly implemented; the strategies exist, but they are not fully operational.

This is where it is important to develop projects that engage children through fun and engaging activities, using interactive technologies to foster emotional and cognitive connections with regional biodiversity. The selection of species used for this project specifically focused on those with the greatest symbolic value for the Hidalgo region and that represent different conservation statuses, ranging from vulnerable species to those with stable populations, yet equally important ecologically for this geographic area. Additionally, a study conducted in 2021 analyzed knowledge of animals in schools in the state of Hidalgo, in the municipalities of Pachuca de Soto, Mineral de la Reforma, and Mineral del Monte, and found that local animals are not the best known in the most urbanized areas, where animals commonly featured in the media and pets predominate, while in more rural areas, farm animals associated with livestock activities—though not native to the region—stand out. This highlights the lack of attention given to endemic species, despite the fact that children are familiar with a wide diversity of animal species, which is an opportunity valued and leveraged by this project.

This approach allows for a comprehensive treatment of the issue, highlighting both species at risk and those that represent successful opportunities in terms of conservation. The biodiversity crisis in Hidalgo is not merely an ecological problem but also a social and cultural one. This is because species loss simultaneously represents the erosion of natural heritage, traditional knowledge, and opportunities for sustainable development. Similarly, it is important to note that the documentation of the state's natural wealth has improved significantly as a result of efforts by the state government, municipal governments, universities such as the Autonomous University of the State of Hidalgo (UAEH), and the National Commission for the Knowledge and Use of Biodiversity (CONABIO), with an emphasis on recovering information about the species present within the state and conducting in-depth research for subsequent dissemination to the general public.

Addressing this issue therefore requires multidimensional approaches that integrate scientific knowledge with community participation and educational innovation.

DEVELOPMENT

The developed system consists of two main interconnected parts that function as a unified whole. The first part consists of a physical interaction interface with a series of buttons representing the answer options for questions about the selected animals. These options allow users to form combinations of three answers that activate a specific LED corresponding to the described animal. The interface incorporates a visual feedback system using multicolored LEDs that indicate the game's status via an amber LED with a timer, errors via a red LED, correct combinations via a flashing blue LED, and identified species via individual amber LEDs.



Figure 1. *Prototype dashboard with questions and answer buttons.*

Source: *Created by the author (2024).*

Furthermore, to make the prototype visually appealing and enhance its educational value, the species are displayed using 3D-printed models housed in individual drawers labeled with their common names and equipped with an amber LED indicator corresponding to the animal found. The models aim to generate interest and allow users to learn about the physical appearance of the animals of Hidalgo. The selection of species is detailed in Table 1.



Image 2. *3D models corresponding to the selected species.*

Source: *Author's own work (2025).*



Image 3. *Detail of the Llanera ground squirrel.*

Source: *Author's own work (2025).*

The second part consists of the processing and control system, based on an Arduino Mega board programmed using a hybrid approach that combines Ladder logic—utilizing the open-source Laddermaker platform—with native programming in the Arduino IDE. This component handles the logical processing, timing, and comprehensive management of the system's inputs and outputs. The game operates with a time limit of ninety seconds per attempt and allows a maximum of three errors. Visual indicators include an amber LED that increases its flashing frequency proportionally to the remaining time, a red LED that activates after three errors, a blue LED that flashes for two seconds upon correct answers, and individual amber LEDs that indicate the correct identification of each species. The timing system incorporates a circuit based on a 555 integrated circuit and a CD4017 counter to manage the advanced visual effects, complementing the main Arduino programming.

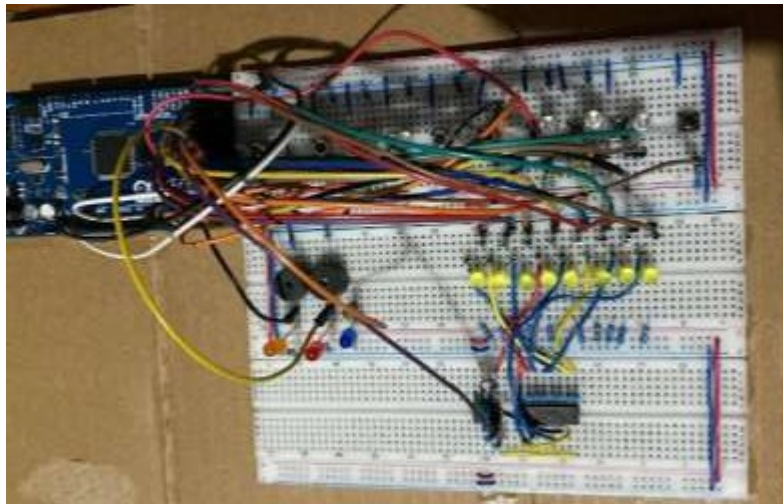


Figure 4. *The proposed circuit assembled on a breadboard.*

Source: Author's own work (2024).

The software was implemented using a dual-track strategy that combines ladder logic—commonly used in the industry and developed in Laddermaker—for the main control logic, with programming in the Arduino IDE, which was used to manage advanced functionalities and address the limitations of Laddermaker when handling a large number of lines of code and outputs. This hybrid approach allowed us to overcome the various technical limitations identified through reverse engineering processes, with the aim of efficiently integrating both programming environments.

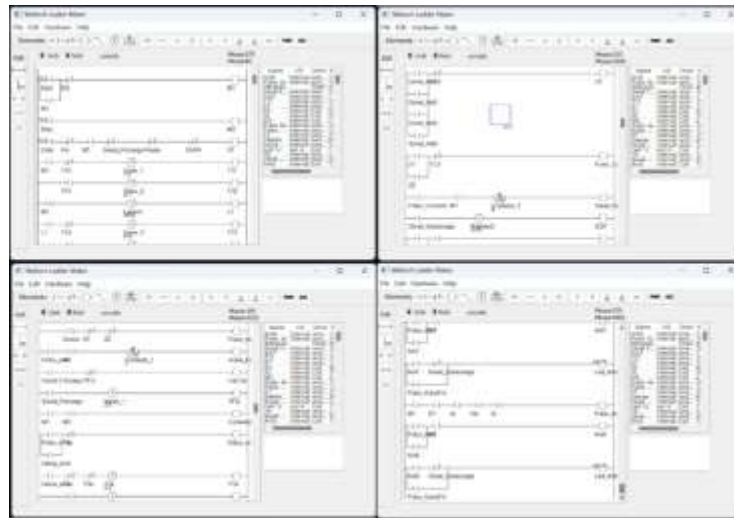


Figure 5. Ladder diagrams in the Laddermaker program.

Source: Author's own work (2024).

To select the species featured in the game, a study was conducted on the native species representative of the state of Hidalgo, taking into account their ecological significance for central Mexico, their symbolic value for Hidalgo's biodiversity, the diversity of their morphological and ecological characteristics, and their conservation status—ranging from vulnerable to least concern. To simplify the questions and facilitate programming, functional feeding categories were grouped, including insectivores with carnivores, herbivores, and omnivores; conservation status, which distinguishes between endangered species—grouping all species at risk of extinction—and non-threatened species; and body covering, which considers fur, scales, and feathers. This categorization allowed for the creation of distinct combinations for each species, facilitating both technical implementation and the learning process through the identification of key characteristics, as shown in Table 1.

Table 1. Table of animal characteristics.

Animal	Scientific name	Diet	Endangerment status	Fur, scales, or feather
◻ Cacomixtle	Bassariscus astutus	Omnivorous	No	Fur
Plains ground squirrel	Cratogeomys fumosus	Herbivore	Yes	Coat
Water snake	Thamnophis cyrtopsis	Carnivore	Yes	Scales
Huasteca Salamander	Chiropterotriton terrestris	Omnivore	Yes	Scales
Mojarra	Herichthys cyanoguttatus	Omnivorous	No	Scales Flamed
Owl	Otus flammeolus	Carnivore	No	Feathers

Eloisa's Hummingbird	Atthis heloisa	Herbivore	No
Feathers	Dwarf Chara	Cyanolyca nana	Carnivore
Yes		Feathers	

Source: *Compiled by the author (2024).*

In addition, cards were designed with more detailed information about the species, which are located at the bottom of the board; these include the common name, scientific name, an image of the animal, its specific conservation status, detailed dietary information, its location within the regions of the state of Hidalgo, and a background illustration depicting the location. This enhances the visual presentation and information about the featured species and improves users' understanding of the content, supporting the educational focus of the exhibit.

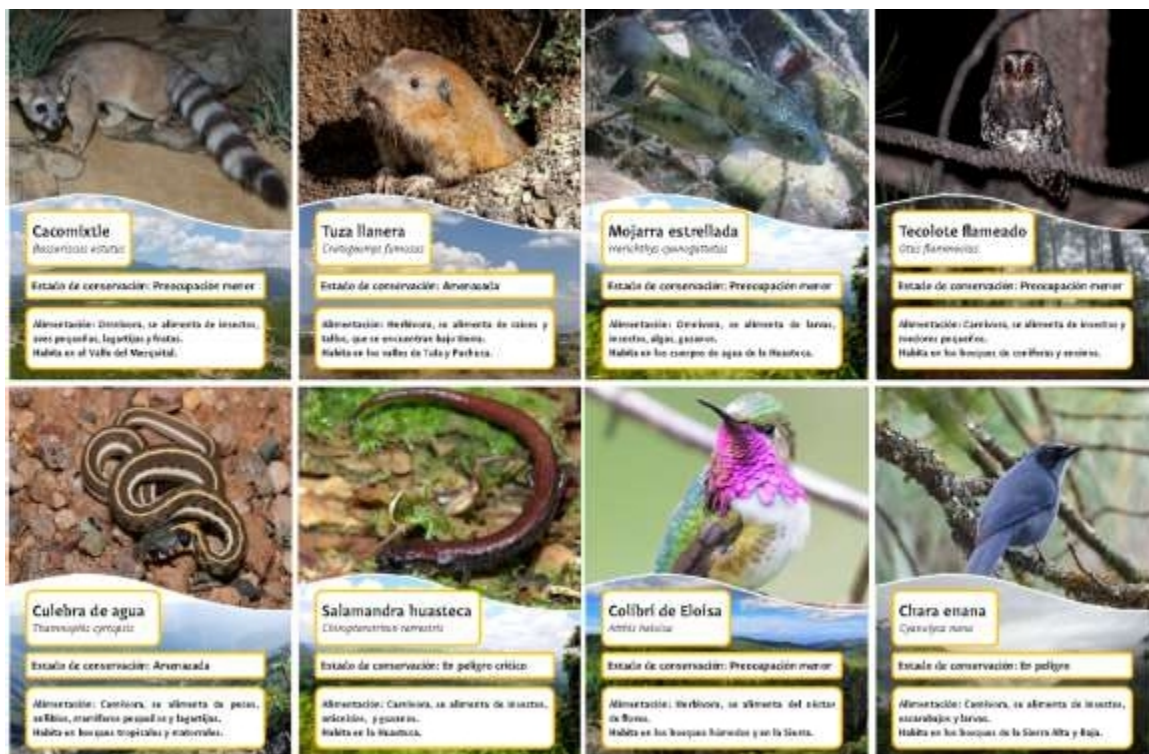


Image 6. *Animal information cards.*

Source: *Author's own work (2024).*

The implemented methodology ensures that the system meets technical objectives and serves as an effective educational tool for promoting regional biodiversity, maintaining scientific rigor in species selection while ensuring the technical functionality of the interactive prototype.

ANALYSIS OF RESULTS

In its implementation, the prototype proved to be an effective tool for science outreach on biodiversity, fulfilling the primary objective of generating interest among young people and introducing them to knowledge about native species in the state of Hidalgo. During the various applications of the prototype, it was observed that the interactive format facilitates the retention of information on the most important ecological characteristics and conservation statuses among participants, particularly among young people. The system developed in this research demonstrated satisfactory technical performance, with stable operation during the various game sessions conducted. The hybrid implementation of the proposed system, in terms of its programming, proved adequate for the required logic, although areas for optimization in future versions were identified. The physical interface developed proved intuitive for users of different age groups, facilitating interaction without requiring detailed instructions, which in some other cases can be complex.

In terms of educational impact, the project developed under this proposal directly contributes to SDG 4 by providing an innovative tool for learning about biodiversity in the central region of the country, particularly in Hidalgo. Feedback from the various participants indicated an increased interest in the conservation of native species, which validates the playful approach as an effective strategy for scientific and ethical outreach.

The scalability potential of the project proposed by students from the School of Engineering at La Salle University in Pachuca was recognized by various local institutions located within the capital of the state of Hidalgo, which have considered implementing it in environmental education projects. This institutional interest reinforces the great relevance of the proposed solution for addressing conservation issues in our country.

Among the limitations identified throughout this project, the need to improve the system to include a greater number of species stands out, without compromising the technical stability already achieved. Additionally, a significant opportunity has been identified to develop more rigorous, effective, and formal evaluation mechanisms that will allow for quantifying the educational impact of this tool in future implementations. The experience gained from this project leads to the conclusion that interactive approaches and proposals represent a highly significant alternative to traditional methods of environmental outreach, particularly when it comes to engaging young audiences.

The success in conveying complex knowledge through an accessible and engaging format validates the technological-pedagogical strategy adopted in this research proposal.

The first presentation of this prototype took place during the 24th Creativity and Ingenuity Contest, organized by the “El Rehilete” Interactive Museum in collaboration with the Hidalgo State Ministry of Public Education, which was held on November 15, 2024. The prototype competed in the “Exploration and Extended Realities” category, alongside ten other projects from various higher education institutions in the state of Hidalgo.

Due to the contest’s format, only one project per category was selected to advance to the final phase; our project competed against nine other teams from different regions of the state, though it did not participate in the contest’s final phase. Subsequently, in December of the same year, the prototype was presented to CITNOVA, an institution belonging to the Government of the State of Hidalgo, and has been considered for collaboration on the project for an Ethnobiological Garden in Tenango de Doria, which is being developed by the council.

The prototype also participated in the 8th Annual Colloquium on Research, Development, and Innovation 2025, organized by La Salle University in Pachuca, where the focus was on using the game as a tool to raise awareness about the state’s endemic animals; it won second place in the Participatory Action Research category.

The prototype’s most recent participation took place at the 26th Lasallian Research, Development, and Innovation Competition 2025 “Brother Salvador González,” held from October 7 to 9, 2025, and organized by La Salle University Mexico at its Condesa Campus. The project competed in the Human and Social Development category, in the University-Level Application Project division. On this occasion, the project was recognized for its use of technological resources to promote environmental conservation, earning it first place in the category.

CONCLUSIONS

Raising awareness about species is one of the key steps in contributing to the conservation of local wildlife. Its importance lies in fostering public interest in the environment they inhabit; therefore, the first strategy to be implemented is to bring these species closer to the public and raise awareness about their presence and the importance of their preservation. Projects of this nature represent a significant contribution to the various scientific outreach efforts regarding the biodiversity of the state of Hidalgo, demonstrating that the use of interactive technologies can effectively generate

interest in and awareness of native species among young people. Through its innovative approach, which combines electronics, programming, and educational content, this research project successfully brings scientific knowledge to the community of Hidalgo in an accessible and engaging way.

The results obtained from the evaluation and implementation of this proposal validated the effectiveness of the methodological approach adopted, where the combination of ladder programming with Arduino IDE allowed for overcoming technical limitations while maintaining the educational essence of the project. The system in question proved to have a robust construction, even under extreme conditions of use, and its interface proved to be intuitive for users of different age groups. **FUTURE WORK**

This prototype opens up multiple opportunities for development and improvement, including the expansion and increase in the number of species represented in the game, as well as the adaptation and modification of the game to focus on and include specific regions of the state of Hidalgo, such as the Mezquital Valley, the Huasteca region of Hidalgo, the Sierra Alta, Sierra Baja, and Sierra Gorda, as well as the plains of Apan and the valleys of Pachuca and Tulancingo, with the aim of highlighting the ecological characteristics of each area. Replicating the prototype to focus specifically on these regions is possible thanks to the ease of manufacturing and accessibility of the components. Additionally, a valuable aspect is the possibility of exploring the project's development in its digital equivalents, which will undoubtedly allow for greater scalability and access, potentially through mobile applications and interactive web platforms. Both methods aim to ensure a wider reach within the state, promoting outreach and raising awareness about Hidalgo's wildlife.

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COLLABORATIVE WORK TABLE

Role	Author(s)
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Validation	Ramírez Hernández Fabián de Jesús, Ordaz Oliver Mario Oscar
Formal Analysis	Mauricio Lavalley Salinas, Fernando Orozco Moctezuma
Research	Fabián de Jesús Ramírez Hernández, Mauricio Lavalley Salinas
Resources	Ramírez Hernández Fabián de Jesús, Orozco Moctezuma Fernando
Data cleansing	Ramírez Hernández Fabián de Jesús, Ordaz Oliver Mario Oscar
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Writing - Review and editing	Mauricio Lavalley Salinas, Mario Oscar Ordaz Oliver
Visualization	Ramírez Hernández Fabián de Jesús, López Navarro Jennifer Karin
Supervision	Oliver Mario Oscar Ordaz
Project Management	Orozco Moctezuma Fernando, Ordaz Oliver Mario Oscar
Fundraising	Ramírez Hernández Fabián de Jesús, López Navarro Jennifer Karin