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INTELIGENT VIRTUAL ASSISTANT FOR UNIVERSITY GARDEN

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ABSTRACT

Building smart territories faces challenges for more efficient services and facilities, as well as supporting the intelligent development of the tourism industry in terms of data analysis and prediction, automation and intelligence, personalization and customization, intelligent decision support, and exploration. In this sense, this paper explores the development of an intelligent tourism agent based on computational intelligence and virtual technologies. It combines an immersive 360° virtual tour with a virtual assistant designed to interact in natural language using a large-scale language model (LLM) and natural language processing (NLP) and natural language understanding (NLU) techniques, integrating dynamically generated responses using natural language generation (NLG) and transmitted to the user using text-to-speech (TTS) technologies. The assistant is a cognitive entity capable of interpreting contextual questions about the tour and offering precise and personalized answers. Outcomes shown a positive impact on the tourist perception of the environment and the contextual acquisition of knowledge about the natural space, therefore this tool demonstrate how virtual assistant and NLP can be applied to the development of immersive solutions for educational and sustainable tourism, promoting accessibility, personalized interaction, and the digital enhancement of natural spaces.

KEYWORDS: Computational intelligence, virtual assistant, NLP, Virtual reality, E-tourism.

1. INTRODUCTION

Computational Intelligence has emerged as a branch of artificial intelligence, focusing on solving complex problems through adaptive techniques such as neural networks, evolutionary algorithms, fuzzy logic, and, more recently, the use of natural language models (Khoshvaght et al., 2025; Ghosh et al., 2023). In recent years, its application has expanded to areas such as knowledge automation, cognitive assistants, and digital tourism (Tuyen et al., 2025; Li et al., 2025; Büyüközkan & Ergün, 2011). In parallel, Virtual Reality has evolved and currently enables the recreation of highly realistic three-dimensional spaces, thereby overcoming geographical and physical barriers (Pérez & Sandoval, 2021). Thus, in the tourism field, Immersive Virtual Reality (IVR) has proven to be an effective tool for offering attractive virtual tours, increasing visitor interest, and facilitating the dissemination of spaces of ecological and cultural value (Patiño Machuca, 2023). When combined with intelligent interaction techniques, its capacity to offer personalized experiences in real time is expanded (Sloan et al., 2022); on the other hand, the development of ecological tourism claims natural spaces as a basis for the socialization of biodiversity and environmental learning, however, sometimes they face challenges such as abandonment, lack of visibility and limited access (Hernández-García et al., 2024), given which, the incorporation of immersive technologies with intelligent virtual assistants not only allows remote exploration, but also promotes active learning by offering contextualized information on flora, fauna and history, strengthening ecological awareness (Freire & Ríos, 2023; Maya et al., 2020).

The use of virtual assistants and artificial intelligence in the tourism industry has yielded positive results in terms of territorial positioning and environmental protection. For instance, “Goio” is the virtual tourist assistant for the island of Tenerife, developed by the Island Council together with the company Intelequia, which was awarded the Tourism Chatbots Award at FITUR 2021 for its ability to respond in Spanish and English, process more than 150,000 interactions, and recommend more than 3,000 sites of interest. Furthermore, it integrates with devices such as Alexa and Google Assistant, facilitating spoken interaction and improving accessibility for tourists who require real-time guidance (Turismo de Tenerife, 2024). Another notable case is “Cicerone AI”, presented as an artificial intelligence solution developed by the company iUrban for tourist offices. It operates in 95 languages and combines a cognitive chatbot with modules for visitor registration, route planning, data analysis, and monitoring tourist behavior. It is implemented in destinations such as Madrid, Ibiza, and Lanzarote, and received the Segittur award for the Best Tourist AI in 2024 (iUrban, 2024).

The design of these scenarios in immersive environments depends not only on the visual content but also on the quality of the audio, the naturalness of the assistant, and the system's ability to answer fundamental questions, which are critical elements in simulating a genuinely immersive experience within a real environment. This project developed a virtual assistant based on Generative AI, capable of understanding and answering user questions using a synthetic voice, thereby creating a more humanized experience. This implementation used computational intelligence tools, such as a large-scale language model (LLM) (Arias-Chávez et al., 2024), specifically GPT-4o mini from OpenAI, which incorporates processing techniques (NLP) (Muñoz Guillena, 2024), generation (NLG), and natural language understanding (NLU) (Cuevas, 2022), along with text-to-speech synthesis (TTS) and speech-to-text recognition (STT) technologies (K. H. et al., 2022), in order to model the tour in the UTM University Garden (Barberán et al., 2023).

Beyond commercial cases such as Goio or Cicerone AI, which were pioneering examples of chatbot applications in tourism, recent scientific literature has moved toward the development of cognitive conversational agents with greater adaptability and contextual depth. Whereas these earlier projects relied on closed dialogue architectures and predefined responses, current approaches integrate large language models (LLMs), retrieval-augmented generation (RAG), and domain-specific knowledge graphs that allow for more precise, personalized, and culturally rich responses.

A representative example is the tourism chatbot framework proposed by Krataithong et al. (2025), which combines GraphRAG with structured cultural and biodiversity data to deliver destination recommendations, routes, and local products in Thailand. The use of hybrid search, mixing structured retrieval with semantic vector search, achieved high levels of precision and recall, while also promoting lesser-known destinations and supporting local economies. This type of system illustrates a level of algorithmic sophistication and social impact that early assistants such as Goio did not reach.

Multimodality has also emerged as a key element in contemporary research. Ferracani et al. (2025)

describe a system that integrates conversational interaction, body movement, and sensory stimuli in digital art contexts, seeking to intensify the emotional bond between visitors and artworks. Ho et al. (2025) extend this approach through multimodal large language models (MLLMs) capable of perceiving and interpreting visual input, enabling conversational agents to provide more nuanced explanations aligned with visitors' aesthetic interpretations. These advances demonstrate that conversational systems are no longer limited to information delivery but function as mediators in the construction of meaning and emotional engagement, a dimension that early applications such as Cicerone AI did not fully achieve due to their reliance on scripted interactions.

Immersion through VR and 360° experiences has become another defining trend. Ly et al. (2025) analyzed how users perceive AI-based assistants embodied in different forms during virtual explorations, showing that the presence of a humanoid avatar or hologram significantly reduced feelings of isolation in single-user VR experiences. Ariya et al. (2025) implemented a generative, multilingual virtual docent in a textile heritage museum, reporting high ratings in visual quality and ease of interaction but identifying challenges related to latency and voice clarity. Huang et al. (2024) examined the integration of ChatGPT with 360° video tours, highlighting the potential for emotional connection and more informed travel decisions. Seripanichkarn et al. (2025) developed a virtual tour of Wat Pho that embedded a conversational agent into an interactive VR environment, while Keerthi et al. (2024) introduced a virtual university campus exploration supported by a chatbot. Collectively, these cases illustrate how the convergence of VR and conversational AI enables more accessible and interactive cultural and educational experiences.

In hospitality and tourism information services, studies have identified measurable effects of chatbots on user perceptions and behaviors. Tosyali et al. (2025) demonstrated that the informativeness of chatbot interactions enhances destination image and, through this mechanism, increases visit intention. Huang et al. (2025) showed that the creative capacity of generative AI can inspire users and strengthen acceptance of hotel recommendations, though lack of transparency generates anxiety that limits this effect. Luo et al. (2025) highlighted that the adoption of generative AI in tourism information search depends on the type of task, the travel motive, and the level of personalization, with non-decision-based searches showing higher adoption and decision-based contexts benefiting from utilitarian motives and tailored task customization. Khreis et al. (2025) found that technical self-efficacy and perceived personalization exert stronger influence on sustained usage intentions than abstract notions of technological superiority. Pandita et al. (2025) demonstrated that digital literacy significantly shapes the evaluation of chatbot quality, with users of higher competence rating chatbots positively, while those with lower competence prefer traditional channels such as email.

The evolution of these systems is not limited to large-scale models. Maylawati et al. (2021) presented a virtual travel assistant using Random Forest for intent classification and RAKE for keyword extraction, achieving strong results in accuracy and recall within a localized domain. Madhu Manjunath and Ravindra (2022) developed a regional tourism assistant using Dialogflow, providing booking and information services. Duguleană et al. (2020) explored voice-based conversational agents in museums, reporting high levels of acceptance from both visitors and staff. These contributions indicate that lightweight or hybrid approaches continue to coexist with LLM-based systems, offering advantages in cost and feasibility while revealing trade-offs in semantic depth and adaptability.

2. METHODS

The research employed a mixed-methods approach. Initially, the inductive method was used to observe and analyse the needs of the target audience about access, interaction and dissemination of natural spaces through digital technologies (Bell et al., 2018), with which the study hypothesis was established, about the effectiveness of virtual reality, combined with artificial intelligence, as a means to improve the tourist experience of the University Garden. Finally, through a critical analysis of the diagnostic results, a technological solution was designed and validated (Bell et al., 2018). The software development methodology used was Scrum, as the environment was changing and results were required in a short timeframe (Lawong & Akanfe, 2025). Finally, the main activities executed are detailed below:

A. Data Collection

To evaluate the perception and effectiveness of the proposed system, a structured survey consisting of seven closed-ended questions was administered. The items were designed to measure aspects such as system usability, the quality of the immersive experience, interaction with the virtual assistant, and the overall usefulness of the tour. The sample consisted of 44 participants, including students, faculty, and administrative staff from the Tourism program at the Technical University of Manabí (UTM). These participants were selected for convenience considering a mix between tourist administrator (4), touring guide (10), and users (34) due to their direct connection to the field of study. This selection allowed for specialized feedback based on educational and professional criteria from the tourism sector.

B. Survey Design

In order to validate the user perception, the ISO/IEC 25010:2011 standard focus on software quality assessment was used. The questions asked are designed to evaluate software quality characteristics as: i) Usability. This means ease of interaction with the virtual assistant, ii) intuitiveness, it should be easy for the user to understand when navigating the tour, iii) functionality both when using the digital board and pressing other buttons, iv) quality the visual content should be pleasing, and the audio should be easy to understand. A liker scale from 1 to 5 was used where 1 is lowest and 5 highest for five question and two binary questions, survey questions are show in Table I.

Table I. Questions of survey.

No.	Question	Scale
1	How intuitive did you find the interface, including the buttons and the digital board for performing different actions within the tour?	1. (Very Easy) 2. (Easy) 3. (Neutral) 4. (Difficult) 5. (Very Difficult)
2	How would you rate the quality of the videos of the different sections of the garden?	1. (Very High Quality) 2. (Good Quality) 3. (Neutral) 4. (Low Quality) 5. (Very Low Quality)
3	How would you rate the quality of the educational audios in the different sections of the garden?	1. (Excellent) 2. (Good) 3. (Fair) 4. (Poor) 5. (Very Poor)
4	How would you rate the virtual assistant's ability to adequately answer your questions?	1. (Very adequate) 2. (Adequate) 3. (Neutral) 4. (Inadequate) 5. (Very inadequate)
5	How smooth was your overall experience on the tour?	1. (Very smooth) 2. (Smooth) 3. (Neutral) 4. (Somewhat smooth) 5. (Very slightly smooth)
6	Do you think the development of the Virtual Tour will increase the visibility of the University Garden?	A. (Yes). B. (No).
7	Does the virtual reality application encourage you to visit the University Garden in person?	A. (Yes). B. (No).

In order to validate outcomes statistic methods was applied as: i) Basic descriptive analysis, it included means, standard deviations, frequencies, ii) comparative analysis, with ANOVA or test of differences between criteria, iii) dimensional reduction, for exploratory Factor Analysis, and iv) criteria ranking for validate the response value order.

C. Architecture

The architecture was based on its compatibility with immersive environments, its robustness for interactive development, and its potential for integrating computational intelligence components. The tools summarized in Table II were used to define the solution's architecture.

Table II. Tools & technologies.

No.	Technologies	Functions
1	Unity	Main engine for building the application, interactivity, and VR.
2	Blender	Software for modelling and animating the virtual assistant.

3	Samsung Gear 360	Immersive 360° video capture.
4	Audacity y Premiere Pro	Audio and video editing and post-production.
5	OpenAI (GPT-4o mini)	The system's computational intelligence engine for generating responses.
6	Google Cloud Text-to-Speech	Conversion of assistant-generated responses into a synthetic natural voice.
7	Whisper (OpenAI)	Speech-to-text (STT) recognition.

The solution architecture required interconnecting: i) Speech Recognition (STT): The user's audio is processed by OpenAI's Whisper in Unity, transcribing it to text for subsequent interpretation through HTTP requests, processing the transcription and activating the conversational logic; ii) Processing and Interpretation (NLU): The transcribed text is sent to the GPT-4o mini API, configured with custom prompt engineering (Chen et al., 2025) that delimits the assistant's thematic domain exclusively to the garden content; iii) Specialized Knowledge Base: The prompt includes official information about the University Garden provided by authorities of the space, categorized by areas of the tour. This allows the assistant to provide coherent answers, segmented by area, based on the visitor's current position in the tour; iv) Response Generation (NLG): The response generated by the GPT model is delivered as rich text, processed by Unity and temporarily stored for presentation; v) Text-to-Speech (TTS): The output text is sent to Google Cloud's Text-to-Speech service, which returns a real-time audio file with natural intonation and a neutral Spanish accent. This audio is played in Unity using an audio source component.

D. Algorithmic and Computational Aspects

The development of the virtual assistant and the virtual reality experience involved the use of various technologies, each playing a crucial role in the creation of the platform. The primary development environment used was Unity, a versatile and powerful tool that allowed the creation of the immersive 360° experience of the University Garden. Unity, with its ability to integrate various types of media, enabled the smooth implementation of the 360° VR videos, while Gear 360 ActionDirector was used for recording and editing these videos. Additionally, the educational voiceovers superimposed onto the videos were generated using Wit.ai's Text-to-Speech (TTS) service, which allowed the creation of natural-sounding voice prompts to guide the user throughout the tour, ensuring the experience was accessible and aligned with the educational content of the garden.

For user interaction with the virtual assistant, the GPT-4o mini model from OpenAI was used to generate responses to user queries. This model was chosen for its ability to understand context and generate coherent and relevant answers within the educational scope of the University Garden. To transcribe the questions spoken by users, Whisper.ai, an advanced speech recognition system, was employed to convert spoken language into plain text. This text was then processed by the GPT-4o mini model, which generates an appropriate response to the posed query.

For converting the generated responses into speech, Google Cloud's Text-to-Speech service was integrated into the system, providing audible and natural-sounding responses, ensuring that the experience remained fully interactive and accessible. This system allowed users to receive information and responses smoothly and audibly, without the need for reading.

To ensure that the assistant had a defined personality and knowledge adapted to the context of the University Garden, customized prompts were implemented within the code. These prompts were designed to guide the GPT-4o mini model, ensuring that responses stayed within the thematic boundaries of the garden, providing only relevant information related to topics such as flora, fauna, history, and the various areas of the garden.

Table III. Customized prompts were implemented.

Section	Instruction/Prompt
General Context of the Assistant	You are a virtual assistant and will respond to the message asked by the user.
Use of Loaded Information	You must respond using the information from your Personality, the Scene, the Introduction content, and the information from your AI model GPT-4o-mini.
Areas of the Garden	In this project, the Garden is divided into 7 distinct areas: Introduction, Area of Introduced Species,

	Palm Area, Humid Forest Area, Native Species Area, Fruit Species Area, Events Area, and Labyrinth. Limit your responses to only the general information and the respective area loaded in the Introduction content.
Response Restrictions	If the user asks a question that is unrelated to the information loaded for you, kindly explain that you cannot answer. Inform them why, either because the question pertains to another area or because you do not have it in your database. If the question is from another area, direct them to the relevant area to ask appropriate questions.
General Information	You can answer general questions about the Garden that pertain to the loaded general information, even if they do not belong to a specific area. Use your GPT-4o-mini model information, if necessary, as long as it relates to the provided garden information.
Use of GPT-4o mini	If the answer the user needs is not in your database, use information from your GPT-4o-mini model to respond, as long as it is relevant.
Memory of Interactions	You are capable of remembering previous answers provided to users. If the user asks a question related to a prior response, you must maintain coherence between answers.
Avoid Errors in TTS	Avoid adding special characters to your responses that could cause conflicts with 'text to speech' services.
Ask for Type of Information	If the user does not specify what type of information they want to know, ask them what type of information they would like to obtain.
Response Limit	Respond in fewer than maxResponseWordLimit words.
Personality	Here is the information about your personality: [personality]
Scene	Here is the information about the scene around you: [scene]
Tour Content	Here is the information corresponding to the respective scene of the tour: [introductionContent]
Action Instructions	[BuildActionInstructions()
User's Message	Here is the user's message: [userMessage]

The Scene and Introduction Content classes are crucial for providing context-aware responses within the virtual assistant system. The Scene class defines the specific environment or area within the University Garden the user is experiencing, such as the Palm Area or the Event Area, allowing the assistant to give precise information related to that section. In contrast, the Introduction Content class holds general information about the garden as a whole, such as its history, mission, and overarching features, which the assistant uses for broad, non-area-specific queries. Together, these classes ensure that the assistant can respond accurately, whether the question relates to a specific area or general knowledge about the entire garden.

A. Building Platform.

An incremental iteration model was used to build the platform, where each increment integrated new functionalities that were iteratively validated, starting with the initial configuration (Iteration #1) and continuing through to integration with the generative AI engine and the designed immersive scenarios (Iteration #7) see details in table IV.

Table IV. Iterations Setting.

Iter.	Description	Output
1	The initial project setup in Unity tool was carried out, including the installation of necessary plugins, configuration of the Meta Quest 2 headset, implementation of interactive controls and design of the initial interface.	• Project setup in Unity. • Integration and configuration of the Meta Quest 2 headset. • Implementation of interactive controls. • Design of the initial virtual tour interface. Valuable feedback was received that allowed us to identify areas for improvement and make necessary adjustments.
2	All interfaces related to the selection of sections of the Botanical Garden that the user wishes to explore were developed. This includes the creation of a selection menu, the implementation of an interface to display specific details for each selected section, and the functionality to initiate a virtual tour of the chosen section.	The following features were introduced: • The Botanical Garden section selection menu. • The detailed interface for each selected section. • The scene-changing feature to start the virtual tour. Valuable feedback was received that allowed us to identify areas for improvement and make necessary adjustments, such: Adjusted navigation between sections, providing a smoother transition by modifying the script responsible for this. Reviewed and improved the visual design of the selection menu, incorporating graphic elements and buttons in a visually appealing way. Added a "back" option to the detailed interface so users can easily return to the selection menu. • Added sound effects to the buttons.
3	A tour was planned, and video and audio recordings were made of the different areas of the university garden to capture visual and audio content	The overall audio quality was improved, and more informative details be added to the videos to help identify which tree is being explained in the 360-degree video. To improve the videos, we used After Effects to add three-dimensional objects to

	that would serve as the basis for the creation of the virtual tour. A 360° camera was used to achieve an immersive experience. Additionally, specialized software was chosen for editing and producing the videos and audio.	the video, significantly enriching the viewer's experience by providing clear and compelling visual indicators that point to the trees being explained. Regarding audio quality, the Mozilla TTS model was completely replaced, and the Oculus Voice SDK TTS models, working in conjunction with wit.ai, were used to generate the audio for the project's videos and tutorials.
4	This process included the creation of rendering textures, specific materials, and the integration of an interactive video playback system that allows users to navigate between different videos via a dashboard.	• Setting up scenes for 360º videos. • Creating rendering textures and materials. • Integrating the Video Player and configuring the Skybox. • Implementing interactive controls on the left controller canvas.
5	It was focused on modelling the virtual assistant for the virtual tour. This virtual assistant will serve as an interactive guide, providing information and assistance to users as they explore the virtual environment.	• Virtual assistance design and no operational prototype
6	The complete virtual assistant was presented.	• Implementation of the virtual assistant backend. • Configuration and mapping of the rendering texture. Integration and functionality of speech recognition and synthesis using the Oculus Voice SDK and Wit.ai. • Implementation of the virtual keyboard for written interaction
7	The project focused on implementing a 2D video player that provides a bird's-eye view of the Garden. This player was added as an additional feature to enrich the user experience, especially for those who want to experience something different.	• Implementation of the 2D video player. • Configuration of the rendering texture and its assignment. • Integration and functionality of the video player on the left side. • Product approval

In the Figure 1 presents a collage of the tool's navigation scenarios. The implementation of the virtual assistant (Avatar) served as the core of the system, integrating various computational intelligence components designed to understand, generate, and respond in natural language within an immersive Unity environment. This virtual assistant was designed as an autonomous cognitive entity capable of interpreting human language, identifying the context of the tour, and providing accurate information about the University Garden in real-time.

Figure 1. Navigation scenarios.

B. *Data analysis protocol.*

The data analysis followed a quantitative, descriptive, and multivariate approach designed to identify patterns, differences, and underlying structures in participants' evaluations of the assessed criteria. To validate its effectiveness, an evaluation was conducted with 44 users, exploring several factors, including navigability, video quality, audio tourist information, virtual assistant support, navigation fluidity, promotional impact, and visitor intent. Each participant filled up a survey with seven questions follow the recommendation of the ISO/IEC 25010:2011 standard focuses on software quality assessment. The questions asked are designed to evaluate software quality characteristics, such as:

- Usability. This means easy of interaction with the virtual assistant.
- Intuitiveness, it should be easy for the user to understand when navigating the tour.
- Functionality both when using the digital board and pressing other buttons.
- Quality the visual content should be pleasing, and the audio should be easy to understand.

All analyses were performed using Python (version 3.x) and its statistical libraries (pandas, numpy, scipy, matplotlib, seaborn, and factor analyser).

Data Preparation and Cleaning.

i. Data were imported from the Excel file LimpiosVT.xlsx.

ii. Initial inspection ensured proper column alignment and variable labelling.

iii. Subsequently, empty rows and non-informative columns were removed, and all variables were converted to numeric format (1–5 scale).

iv. Outliers and missing data were examined and corrected to ensure analytical consistency.

v. The Quality factor was unified for the best analysis in agree with the ISO/IEC 25010:2011 criteria.

vi. In order to improve de inferential tests, the sample was extended to N=500 per criterion for approximate.

Descriptive Statistics, including the mean (M), standard deviation (SD), minimum, and maximum values, were computed for each criterion. This step summarized the general distribution of responses and identified potential concentration or skewness in participant perceptions. Moreover, to enhance interpretability, bar charts and radar plots were used to visualize comparative trends among the criteria.

Comparative Analysis (ANOVA).- To test whether mean scores differed significantly across criteria, a one-way analysis of variance (ANOVA) was conducted. Were, H_0: There are no significant differences among the mean scores of the evaluated criteria, and, H_1: At least one criterion shows a significantly different mean score. A significance threshold of $\alpha = .05$ was applied. When p values were below this level, results were interpreted as statistically significant differences in perception among criteria.

Criteria Ranking. - Mean scores for each criterion were calculated and arranged from highest to lowest to establish a performance ranking. It identified both strengths (criteria with the highest scores) and areas for improvement (those with the lowest scores), and a heatmap visualization illustrated the intensity and distribution of perceptions across all criteria, facilitating an intuitive understanding of performance disparities.

Integrative Interpretation. - In order to synthesized the outcomes into an executive summary the follow criteria were follow: Key strengths that should be maintained as competitive advantages, priority areas requiring improvement, strategic recommendations for resource allocation and process optimization.

3. RESULTS

The main participant's feedback, a descriptive explanation is presented in Table V. In table V, the must of participant presents very pleasant their interaction with the virtual assistant, however, there are data in low and hight part of the scale, moreover the question six (6) and seven (7) are overloading, therefore these rows are deleted from the dataset statistics analytics.

Table V. Outcome's summary.

No.	ISO/IEC Feature	Factor	Outcome
1	Intuitiveness	Navigability	68.2% of users rated the interaction with the menus and the digital display as "Very easy," while 25% considered it "Easy."
2	Quality	Video Quality	86.3% of respondents positively evaluated the 360° videos, highlighting their clarity and visual richness.
3	Quality	Audio Tourist Information	95.5% indicated that the audio information was rated as "Excellent" or "Good," validating the integration of the audio component as part of the immersive environment.
4	Usability	Virtual Assistant Support	93.2% stated that the agent responded appropriately to their

			queries, highlighting the accuracy and naturalness of the interaction
5	Functionality	Navigation Fluency	97.8% reported a "Very Fluid" or "Fluid" experience, with no significant interruptions.
6	Usability	Promotional impact	100% felt that the tour increased the visibility of the University Garden.
7	Usability	Visit intention	All participants expressed a sense of motivation to visit the site in person after the virtual experience.

Statistics analysis was development using python language applied the protocol defined for the four main dimensions: Usability, Intuitiveness, Functionality, and Quality. The findings shown, that the overall, the mean scores ranged between M = 4.49 and M = 4.78 on a 5-point scale, it suggesting generally favourable perceptions of the evaluated aspects, in this sense, the standard deviations were moderate (SD = 0.487– 0.737) where its coefficient of variation CV = 15.6%, which means moderate variability, it means, a reasonable degree of consensus among participants. The visual inspection with bar plots (Figure 2) revealed that criteria, that Functionality and Intuitiveness received the highest mean scores, while were Usability and Quality rated somewhat lower. Participants valued positively the virtual assistant in agree with the user requirements, as well as the perception for understanding of navigation flow and the responsiveness of interactive functions, however, they perceived the need to improvement the interaction with the and the visual and auditory quality of the experience.

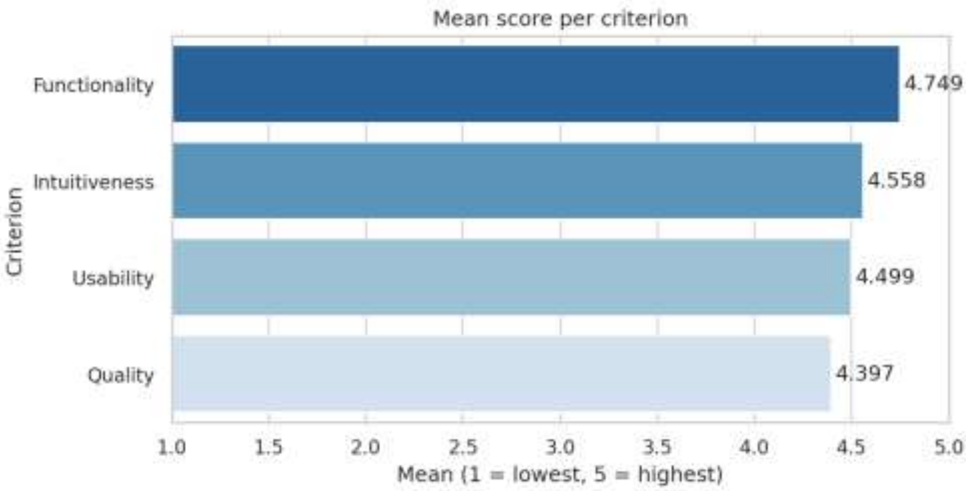

Figure 2. Mean of response by participants.

The analysis One-way ANOVA was conducted to determine whether significant differences existed among the mean scores of the four evaluated dimensions, it revealed a statistically significant effect, $F(3, 2511) = 31.791$, $p < .001$; $h^2 = 0.0366$, indicating that statistically significant differences across criteria where at least one dimension was evaluated differently from the others.

The Ranking of Dimensions (Table IV), the mean scores were ranked from highest to lowest to identify strengths and improvement areas, additionally, the correlation analysis (Figure 3), showing stronger correlations in quality – usability, follow up for usability and intuitiveness, it means that the quality of virtual assistant trend to improve the usability, and the intuitiveness.

Table IV. Ranking of Dimensions summary.

Rank.	Dimension	Mean (M)	SD	Interpretation
1	Functionality	4.748	0.487	Strength. - Users find the assistant is adequate for solve the problem
2	Intuitiveness	4.555	0.721	Positive perception, It is easy for the user to understand when navigating the tour.
3	Quality (Video & Audio)	4.395	0.737	Visual content should improve the images, and audio should be easy to understand, since it did not understand clearly the messages
4	Usability	4.499	0.622	The interaction did not allow full understanding, it requested assistance.

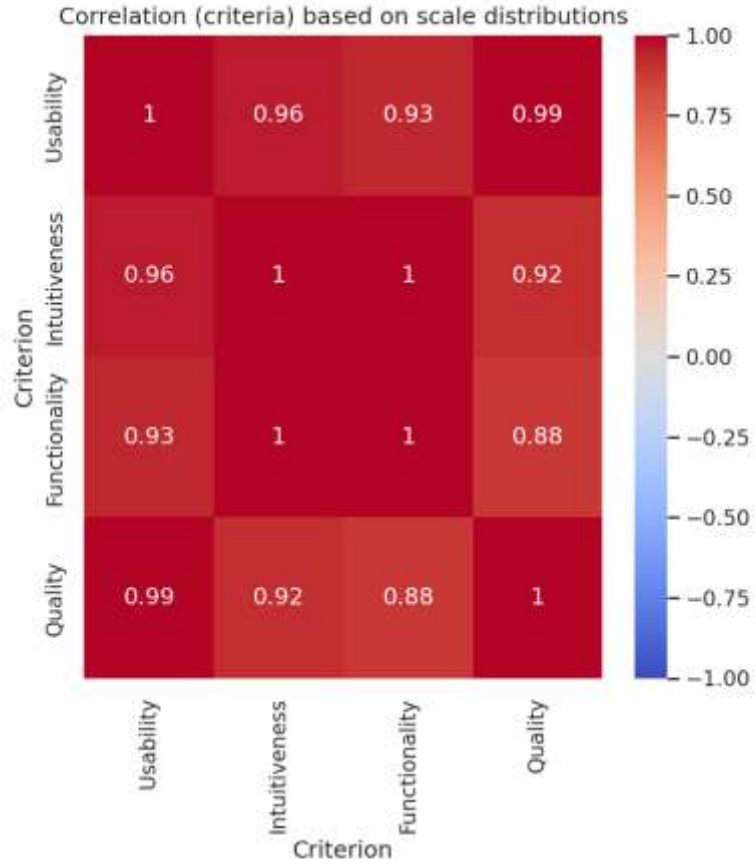

Figure 3. Correlations between criteria.

Summarizing statistics analysis, it reveals a clear differentiation among the evaluated dimensions, where, stand out Functionality and Intuitiveness as the virtual assistant's strongest attributes, reflecting effective requirements compliance and sensory appeal; and, Usability and Quality emerge as priority areas for improvement, suggesting a need for enhanced interface guidance and more responsive interaction mechanics.

In the other hand, the user feedback validates the increased accessibility achieved through the use of 360° videos, which facilitate remote access to the garden. The combination of visual environments, contextual audio, and intuitive navigation enhanced the sensory perception of the space, thanks to the integration of computational intelligence technologies (LLM, NLP, NLG, TTS, and STT). Participants were able to maintain coherent and relevant conversations about the different areas of the garden. Finally, the added value of the tour as a tool to promote ecotourism was fully recognized, therefore, the virtual tour system shown as effectiveness alternative for as educational tool, for promoting local tourism.

4. DISCUSSION

The performance evaluation of the virtual assistant was not limited to internal algorithm testing; instead, a validation process was implemented that included both intrinsic and extrinsic metrics. The intrinsic metrics focused on assessing the semantic coherence of the generated responses, ensuring that the answers were logical, well-structured, and relevant to the user's queries. In addition, grammatical accuracy and relevance of the responses were evaluated, which allowed for adjustments to the model's parameters to improve its performance.

Extrinsic metrics, on the other hand, were based on user perception. To assess this, a structured survey based on the ISO/IEC 25010:2011 standard was used, which measures usability, reliability, and user satisfaction. The results showed that participants perceived the virtual assistant positively across all four measured indicators (all means > 4.0 on a 1–5 scale). However, the pattern of differences is meaningful:

In agree with the ISO/IEC 25010:2011 standard, we found the follow findings: i) Functionality scored highest (M = 4.758), suggesting that interactive behaviours responses from the digital board, button interactions, and general responsiveness, these are a strength of the system. Moreover, the relatively low SD (≈ 0.48) indicates consistent performance across respondents. Ii) Intuitiveness (M = 4.563) and Usability (M = 4.500) were also rated positively, however showed more variability (SD ≈ 0.71 and 0.63, respectively). This means that while many users find the system intuitive and easy to interact with, a minority report misunderstanding consistent with the higher SDs. Quality (M = 4.407) had the lowest mean and the highest variability (SD ≈ 0.72); since, the "Quality" was unified across visual and audio items, this result suggests heterogeneous perceptions of media polish and audio clarity, where some users perceived the multimedia assets as very strong while others did not. The significant ANOVA statistically significant effect, $F(3, 2511) = 31.791$, $p < .001$; $h^2 = 0.0366$, indicating that statistically significant differences across criteria where at least one dimension was evaluated differently from the others, therefore we accept the H_1.

The virtual assistant presented a couple of main limitation, the first on related with the Platform, and de the other with de sample and data set.

i) Platform Limitations

Despite the advancements in creating this virtual assistant, there are several limitations inherent to the technology employed. First, the reliance on an internet connection is a significant limitation, as the system depends on the API of the GPT-4o mini model and other cloud services, which requires a constant connection for proper functioning. In environments with limited technological infrastructure or areas with poor network coverage, the system might experience latency or service interruptions.

Another important limitation lies in the quality of the knowledge base used to configure the prompts. While official information about the University Garden was used to create the knowledge graphs, the completeness and accuracy of this information is crucial for the quality of the generated responses. A lack of representative data in some areas may lead to responses that are too general or imprecise.

Finally, while prompt engineering and the GPT-4o mini model help reduce errors known as "hallucinations" (incorrect or irrelevant responses generated by the model), it is not possible to eliminate them entirely. This means that, despite efforts to adjust the prompts and the model, some responses may not be fully accurate or contextually appropriate, requiring continuous human supervision to ensure the reliability of the system.

i) Data Limitations

The inferential outcomes derive from aggregated proportions that were converted into a pseudo-sample to enable statistical testing, allows setting the reliable degrees of freedom and variance estimates would be obtained only from respondent-level data (one row per participant). Thus, while the ranking and broad conclusions are robust for prioritization, inferential claims (exact p values and effect sizes) should be validated with raw respondent data when available.

The ethical and data protection considerations, were applied, in this sense, the analytic procedures complied with established ethical standards for research involving human data. The dataset used in this study contained only aggregated and fully anonymized information, ensuring that no personally identifiable information (PII) was processed or stored. The handling of these data adhered to the principles of transparency, data minimization, and lawful processing as outlined in Organic law on the Protection of Personal Data of Ecuador. i)User Privacy. No individual-level identifiers were collected or retained at any point. Aggregation at the indicator level prevented reconstruction of individual user profiles and thereby reduced the risk of re-identification, in agree with the institutional laws. Ii) Bias in AI Responses. The algorithmic bias was recognized as an ethical aspect. Therefore, the systematic bias can emerge from the training data or response-generation model. To mitigate these risks, this research followed to Binns et al., (2018), where they recommend ongoing bias auditing, model retraining with diverse corpora, and human-in-the-loop review to ensure fairness and neutrality across the groups. iii) Inclusivity and Accessibility. In agree with the principles of equitable design, the virtual assistant should accommodate diverse user needs, including linguistic variation, accessibility for individuals with disabilities, and cultural sensitivity in language and interface elements, and finally, iv) the data retention and transparency, where, only data necessary for the declared research purposes were retained; however, the participants should be informed in future research, about the consent documentation, where their information is used and their rights to access, correct, or request deletion of their data, in accordance with Organic law on the Protection of Personal Data of Ecuador.

5. CONCLUSIONS

The data collected through surveys and controlled tests suggest that this solution could have a positive impact when applied in real-life scenarios, as it improves accessibility and democratization of knowledge, promotes Environmental Education, and contributes to the Digital Transformation of tourism with disruptive technology. In short, this solution presents reliable and consistent behaviour, focusing on the user experience, which opens up a range of options to promote the sustainable tourism sector, that is aligned with the other experience around the word, however some recommendation emerging, as : Preserve Functionality and use functionality as a baseline for evaluating new features implemented or improving, try to progress with the Quality of video (consistent templates, image quality, responsive scaling) and sounds (mastering (noise reduction, volume normalization, multi-bitrate delivery), running in a specific device QA (mobile, tablet, low bandwidth) to reduce variance in user perception, lastly implementing small, testable interface changes(short guided onboarding, contextual hints, prominent affordances for interactive elements, and improved labelling), where these will validate with task-based usability sessions focused on users who rated these indicators lower to identify concrete friction points.

In the context of real utility, the virtual assistant, the people who have tried the virtual tour system have shown an interest in physically visiting the garden, suggesting the potential for attracting more visitors in the future. This interest generated by the virtual tour is a strong indicator that the project is meeting its primary objective of increasing the visibility and appeal of the University Garden as a tourist and educational destination, additionally, the inclusion of educational audio and visual content has added educational value, facilitated users' learning and understood of the garden's features. In short, this research has achieved its stated objectives and created an innovative tool that not only enhances the perception of the University Garden but also promotes its natural and educational richness to a wider audience. However, we are aware that the outcomes respond to local context, therefore, these finding should not be considered for generalization in this version.

Open issues are related with, expand the amount of educational content within the tour, incorporating more details about the areas, plants, and animals that are being introduced to the university garden, moreover, the visual quality of the videos must also be further improved, in this sense, future research that could be integrated includes creating a multilingual version for international audiences, incorporating augmented reality (AR) or smart guided tours, and implementing behavioural analytics modules to tailor content to user preferences and continuously improve the experience, and should intentionally recruit participants from heterogeneous demographic and ability groups to promote representational inclusivity follow he recommendation of WAI Guidelines, (2022).

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