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Research on Rural Settlement Landscape Visualization and Participatory Planning Based on Virtual Reality and Augmented Reality Technology

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Abstract: Rural settlement planning stands at the intersection of economic growth, environmental preservation, and stakeholder satisfaction, necessitating innovative approaches to inform well-balanced decisions. The paper presents an innovative approach to rural settlement landscape visualization and participatory planning through the integration of virtual reality (VR) and augmented reality (AR) technologies. Leveraging a novel probabilistic model based on Generative Adversarial Networks (GANs), the study explores various scenarios by simulating realistic landscapes that account for economic viability, environmental sustainability, and stakeholder satisfaction. The GAN-augmented virtual reality model allows stakeholders to immerse themselves in different scenarios, enhancing engagement and collaboration. The paper evaluates scenarios across diverse dimensions, offering a comprehensive understanding of trade-offs and synergies. Findings underscore the significance of balanced land use distribution, population density, and economic impact. The integration of VR and AR technologies further fosters participatory planning, enabling stakeholders to visualize and comprehend diverse scenarios more effectively. This interdisciplinary approach bridges computer science, urban planning, and environmental sustainability, contributing to evidence-based decision-making and resilient rural development. The paper's methodologies and insights equip urban planners, policymakers, and researchers with valuable tools for crafting sustainable rural communities.

Keywords: *Rural Settlement, Landscape Visualization, Virtual Reality, Probabilistic Model, Economic Growth, Generative Adversarial Network (GAN)*

1. Introduction

Virtual reality (VR) is a transformative technology that immerses users in a simulated environment, blurring the line between the physical and digital worlds. Through the use of specialized headsets and sensory devices, VR creates a highly realistic and interactive experience, enabling users to explore and interact with virtual landscapes, scenarios, and objects [1]. By stimulating multiple senses, including sight, sound, and sometimes even touch, VR transports individuals to entirely new recreates familiar settings with unprecedented levels of detail and authenticity. Beyond its applications in gaming and entertainment, virtual reality has found utility in fields like education, healthcare, architecture, and training, offering innovative ways to learn, communicate, and engage with information [2]. As VR technology continues to advance, it holds the potential to revolutionize the way perceive and interact with both the digital world around us [3]. Virtual reality (VR) is an advanced technology that has the power to revolutionize the way experience and interact with digital content. By utilizing cutting-edge hardware such as VR headsets and motion-tracking devices, VR creates a simulated environment that engages multiple senses simultaneously, primarily sight and sound [4]. This immersive experience transports users to a computer-generated world that can be entirely fictional, based on real locations, or a mix of both. One of the key elements of VR is its ability to provide a sense of presence – the feeling of being physically present in the virtual world [5]. This is achieved through the use of 3D graphics, stereoscopic displays, and head-tracking technology that adjusts the perspective in real-time as the user moves their head [6]. This level of immersion enables users to explore their surroundings, interact with objects, and even collaborate with others as if they were truly there. The applications of virtual reality extend far beyond the entertainment. In the field of education, VR can transport students to historical events, distant planets, or complex scientific concepts, making learning more engaging and memorable [7]. Medical professionals use VR for training simulations, allowing surgeons to practice procedures in a risk-free environment. Architects and engineers can visualize and even walk through their designs before they are built, aiding in the design and planning stages [8]. With VR has therapeutic potential in healthcare, aiding in pain management, exposure therapy for phobias, and rehabilitation exercises [9]. It has the ability to transport individuals with mobility limitations to places they may never physically reach. Socially, VR can connect people from around the world in shared virtual spaces, fostering new forms of communication and collaboration.

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Despite its immense potential, VR technology still faces challenges. Issues such as motion sickness, the need for powerful hardware, and the high cost of quality equipment can hinder its widespread adoption [10]. However, as technology advances, these challenges are being addressed, making VR more accessible and user-friendly. Virtual Reality (VR) has introduced a paradigm shift in the domain of rural settlement landscape visualization and participatory planning, revolutionizing the way communities engage with the development process [11]. This technology offers a multidimensional approach that transcends traditional 2D maps and static presentations, allowing stakeholders to step into a dynamic, immersive virtual environment where proposed changes come to life. Incorporating VR into rural planning enables a collaborative and inclusive approach. Local residents, community leaders, planners, and experts can gather together virtually to explore intricate 3D models of their landscape [12]. This hands-on experience fosters a deeper understanding of the implications of various planning decisions. For instance, inhabitants can virtually walk through new infrastructure projects, experience changes in the local environment, and visualize how proposed developments may alter their daily lives [13]. Crucially, VR-based participatory planning empowers rural communities to voice their opinions and concerns [14]. Through this interactive platform, residents can provide real-time feedback, suggest alterations, and express their preferences, ensuring that planning decisions are well-informed and reflective of the collective vision [15]. This approach transcends geographical barriers, allowing remote stakeholders to be equally involved, which is especially significant in rural areas where physical meetings might be challenging.

The visualization capabilities of VR facilitate scenario testing and impact assessment. Planners can create multiple development scenarios and showcase them in the virtual environment enabling stakeholders to witness the potential outcomes [16]. This proactive strategy aids in identifying potential challenges, such as environmental stressors, infrastructural limitations, or social disruptions, which can then be addressed before implementation, fostering sustainable and resilient rural developments. Furthermore, VR-driven participatory planning encourages a more holistic consideration of the rural landscape [17]. It allows for the integration of cultural heritage, historical significance, and ecological sensitivity into the planning process. By providing an immersive experience that highlights the intricate relationships between elements, VR prompts a richer dialogue on how development can harmonize with the existing fabric of the community [18]. Augmented Reality (AR) has emerged as a transformative tool in the rural settlement landscape visualization and participatory planning, reshaping how communities engage with the development process. By overlaying digital information onto the real-world environment, AR allows stakeholders to directly interact with their surroundings while accessing dynamic visualizations of proposed changes [19]. This technology facilitates a collaborative and inclusive approach, enabling residents, planners, and experts to physically be in the landscape and interact with digital models in real time. AR-based participatory planning brings planning concepts to life, making them accessible and comprehensible to a wider audience. Community members can use their smartphones or AR glasses to see how new infrastructure, buildings, or landscapes will look and feel in their immediate surroundings [20]. This real-time visual feedback fosters a more informed understanding of the proposed changes and their potential impacts, allowing residents to make more insightful contributions to the planning process.

One of the key benefits of AR is its ability to seamlessly integrate the digital and physical worlds. Stakeholders can stand on a particular spot within the rural landscape and use AR to visualize how different scenarios would appear from that vantage point [21]. This level of situational awareness empowers communities to assess the visual, social, and environmental dimensions of development choices from their unique perspectives, leading to more contextual and responsive planning outcomes. Moreover, AR enhances communication and collaboration among stakeholders. By enabling individuals to share the same augmented view of the landscape, regardless of their physical location, AR breaks down geographical barriers [22]. Remote participants can join virtual meetings, collaborate on design choices, and contribute their insights in a cohesive and interactive manner. This inclusivity ensures that diverse voices are heard and considered in the planning process. AR-driven landscape visualization and participatory planning also open avenues for environmental impact assessment and sustainable design [23]. By layering data about terrain, vegetation, water flow, and more onto the physical landscape, planners can evaluate how proposed changes might affect the ecosystem and identify potential challenges beforehand [24]. This proactive approach supports the creation of resilient and environmentally conscious rural developments.

The paper makes significant contributions to the rural settlement landscape visualization and participatory planning through its innovative approach and integration of cutting-edge technologies. By combining the power of Generative Adversarial Networks (GANs), virtual reality (VR), and augmented reality (AR), the paper introduces a novel probabilistic model that enables the simulation and visualization of various scenarios. This approach breaks new ground by offering a multi-dimensional evaluation framework that considers economic viability, environmental sustainability, and stakeholder satisfaction as interconnected factors. The integration of VR and AR technologies enhances the participatory planning process, allowing stakeholders to immerse themselves in realistic scenarios and fostering better engagement and collaboration. The paper's exploration of a diverse range of scenarios, each characterized by varying land use distributions, population densities, and economic impacts, demonstrates its applicability across different contexts. The presentation of numerical results, evaluations, and data-driven insights offers tangible guidance for evidence-based decision-making in rural settlement planning. Moreover, the paper emphasizes the importance of achieving balanced and sustainable development by addressing economic growth while considering environmental preservation and stakeholder contentment. Through its interdisciplinary approach, the paper bridges concepts from computer science, urban planning, and environmental sustainability. This unique convergence of fields contributes to a holistic understanding of rural settlement planning challenges. In practical terms, the paper's methodologies and findings provide valuable tools for urban planners, policymakers, and researchers engaged in creating resilient and thriving rural communities.

2. Related Works

VR-based rural settlement landscape visualization and participatory planning offer an innovative approach that engages communities on a profound level. By bridging the gap between abstract plans and tangible experiences, VR empowers stakeholders to actively shape their environment, leading to more comprehensive, sustainable, and locally relevant rural developments. As this technology continues to evolve, its potential to enhance collaboration, decision-making, and the overall quality of rural life remains promising [25]. AR-based rural settlement landscape visualization and participatory planning offer a dynamic and interactive approach that bridges the gap between abstract plans and the tangible environment. By enabling stakeholders to experience proposed changes firsthand, AR enhances understanding, communication, and collaboration, ultimately leading to more thoughtful, sustainable, and community-driven rural development outcomes. As AR technology continues to advance, its potential to revolutionize how to plan, visualize, and interact with our surroundings becomes increasingly evident. Jang et al. (2021) [26] contribute to the field of educational technology by exploring the factors that influence the adoption and acceptance of augmented reality (AR) and virtual reality (VR) for learning. As these immersive technologies become more prevalent in educational settings, understanding how learners perceive and engage with them is crucial. The study likely investigates aspects such as ease of use, perceived usefulness, and the influence of social norms on learners' decisions to use AR and VR. These insights can guide educators and policymakers in designing effective and engaging learning experiences that harness the capabilities of AR and VR.

Talwar et al. (2022) [27] address the post-pandemic context of sustainable tourism, emphasizing the potential of virtual reality (VR) to enhance the tourism industry's resilience. The study likely explores how VR can offer virtual travel experiences that minimize physical travel's environmental impact while still providing tourists with immersive and engaging experiences. This aligns with the broader concept of sustainable tourism, which seeks to balance economic benefits with environmental and social considerations. Akdere et al. (2021) [28] focus on the role of virtual reality (VR) technology in developing intercultural competence. In a globally interconnected world, the ability to understand and appreciate diverse cultures is crucial. VR offers a unique platform to immerse individuals in different cultural contexts, fostering empathy, understanding, and effective communication across cultures. The study likely investigates the effectiveness of VR-based intercultural training programs and their impact on enhancing cross-cultural competencies. Rojas-Sánchez et al. (2023) [29] contribute to the field of educational research by conducting a systematic literature review and bibliometric analysis on the topic of virtual reality (VR) and education. By analyzing a wide range of studies, this research provides a comprehensive overview of the trends, topics, and gaps in the existing body of knowledge. This work is valuable for identifying research directions, emerging themes, and areas that require further exploration in the intersection of VR and education.

Raja and Priya (2021) [30] provide a conceptual overview of the historical origins, technological advancements, and impacts of using virtual reality (VR) technology in education. This study likely traces the evolution of VR in educational contexts, from its conceptual beginnings to its current applications. By examining the technological advancements that have shaped VR's capabilities, the authors shed light on how VR has transformed educational practices, providing more immersive and engaging learning experiences. Albus et al. (2021) [31] investigate the influence of signaling in virtual reality (VR) on learning outcomes and cognitive load. In a VR environment, cues and signals play a significant role in guiding learners' attention and comprehension. The study likely explores how visual and auditory cues within VR experiences impact learners' understanding, retention of information, and the cognitive effort required to process complex content. This research has implications for designing effective instructional cues in VR learning environments. Marks and Thomas (2022) [32] examine the adoption of virtual reality (VR) technology in higher education over multiple teaching semesters. As higher education institutions increasingly integrate VR into their curricula, understanding its adoption trends, challenges, and benefits is essential. This study likely evaluates students' and educators' experiences with VR, considering factors such as usability, engagement, and the technology's alignment with learning objectives.

Dincelli and Yayla (2022) [33] present a hybrid-narrative review of immersive virtual reality (VR) within the context of the evolving Metaverse concept. The Metaverse envisions a collective virtual shared space, bridging physical and digital realities. This study likely explores how immersive VR experiences contribute to the Metaverse's development, including their potential affordances, challenges, and implications for communication, social interaction, and information sharing. Singh et al. (2021) [34] focus on enhancing practical education through the use of virtual reality (VR) learning environments in electronics engineering laboratories. This research likely showcases how VR can provide students with hands-on experiences in virtual spaces, enabling them to experiment, learn, and troubleshoot in a controlled and interactive setting. The study's findings could guide the development of VR-based educational tools in technical fields. Puggioni et al. (2021) [35] introduce ScoolAR, an educational platform that leverages virtual reality (VR) to enhance students' learning experiences. This likely involves creating interactive and immersive virtual environments that allow students to engage with complex concepts in an intuitive and engaging manner. The study's focus on improving learning outcomes aligns with the broader goal of using technology to enhance education's effectiveness. Reeves et al. (2021) [36] contribute to the field of psychology and mental health by conducting a randomized controlled trial on 360-degree video virtual reality (VR) exposure therapy for public speaking anxiety. This research likely examines how VR can provide a controlled and immersive environment for individuals to confront and manage their anxiety. The study's findings could inform the development of therapeutic interventions using VR technology.

Subawa et al. (2021) [37] study the practices of virtual reality (VR) marketing in the tourism sector, using a case study of Bali, Indonesia. This research likely investigates how destinations leverage VR to promote tourism experiences and attract visitors. The study's focus on the tourism industry's adoption of VR aligns with the growing trend of using immersive technology to showcase travel destinations. Raja and Lakshmi Priya (2022) [38] empirically study the use of virtual reality (VR) and augmented reality (AR) with information and communication technology (ICT) tools to enhance the quality of education during the COVID-19 pandemic. This likely involves assessing how VR and AR, along with digital tools, can facilitate remote and hybrid learning, maintaining educational quality amidst unprecedented challenges. Gall et al. (2021) [39] explore how embodiment in virtual reality (VR) intensifies emotional responses to virtual stimuli. This research likely investigates the intricate relationship between the user's physical presence in a VR environment and the emotional reactions triggered by simulated experiences. Understanding how VR can evoke strong emotional responses has implications for various fields, including psychology, entertainment, and marketing.

These studies delve into how VR and AR can enhance education by examining factors influencing technology acceptance, tracking historical and technological evolution, and creating immersive learning environments. Additionally, research explores VR's potential in intercultural competence development and AR's role in sustainable tourism. The studies investigate the integration of VR in higher education, from optimizing teaching methodologies to addressing anxiety disorders through exposure therapy. VR's influence on marketing practices, particularly in the tourism sector, is also explored. Moreover, the collection delves into how embodiment in VR intensifies emotional responses. Collectively, these works provide valuable insights into the transformative power of VR and AR, shedding light on their implications for education, psychology, tourism, and beyond, shaping a more immersive and interconnected future.

3. GAN Augmented Virtual Reality Probabilistic Model

GANs are a type of machine learning model that involves two neural networks, a generator, and a discriminator, competing against each other. GANs are commonly used to generate realistic and high-quality data, such as images or textures, by learning from existing data and generating new samples that resemble the original data. Augmented VR refers to a combination of augmented reality (AR) and virtual reality (VR) technologies. AR involves overlaying digital information or objects onto the real world, enhancing the user's perception of their surroundings. VR, on the other hand, immerses users in a completely digital environment. Augmented VR likely involves blending both these technologies to create immersive and interactive rural settlement visualizations. In the context of rural settlement planning, a probabilistic model could involve predicting various outcomes or scenarios based on probability distributions, which can be useful for decision-making and planning processes. Visualization techniques can range from 2D maps to 3D interactive models, providing insights into how rural areas are structured, the distribution of resources, and potential development scenarios. It involves using advanced technologies like GANs and AR/VR to create immersive and realistic visualizations of rural landscapes. Additionally, the incorporation of probabilistic models could enable the exploration of various development scenarios, considering uncertainties and probabilities. The participatory planning aspect indicates that local communities and stakeholders play a role in shaping these development scenarios, ensuring a collaborative and inclusive planning process. Figure 1 illustrates the landscape view of the rural area computed with virtual reality.

Fig 1: Landscape View of Rural Area

The process of using a Generative Adversarial Network (GAN) for Rural Settlement Landscape Visualization and Participatory Planning involves several stages that integrate GAN technology, virtual reality (VR) or augmented reality (AR) visualization, probabilistic modeling, and collaborative community engagement. The process starts with collecting spatial data related to the rural settlement, including topography, land use, infrastructure, and other relevant information. This data is then preprocessed to ensure consistency, accuracy, and compatibility for further analysis. A probabilistic model is created based on the preprocessed data. This model could involve predicting various outcomes or scenarios related to the settlement's growth, development, resource allocation, and other factors. The model takes into account uncertainties and uses probability distributions to generate different possible scenarios. The GAN component comes into play to generate realistic and diverse visualizations of the rural settlement landscape. The GAN consists of two neural networks: a generator and a discriminator. The generator generates synthetic landscape images, while the discriminator evaluates the authenticity of these generated images compared to real images. The networks iteratively train against each other, with the generator improving its ability to create realistic images over time. The outputs of the GAN, along with the real data, are integrated to create a comprehensive dataset of landscape images. These images represent a range of potential scenarios, as generated by the GAN and informed by the probabilistic model. Augmented VR/AR technology is then employed to overlay these images onto the real-world rural landscape. This creates an immersive experience where stakeholders can view different development scenarios in real-time, as if they were physically present in the landscape. The augmented VR/AR visualization is made accessible to stakeholders, including local communities, urban planners, policymakers, and other relevant parties. This step facilitates participatory planning by enabling stakeholders to interact with the virtual landscape and experience various potential development scenarios. Through this process, stakeholders can provide feedback, suggest modifications, and collectively make informed decisions about the settlement's future.

Collect spatial data: Collect data such as elevation, land use, infrastructure, and other features of the rural settlement.

Preprocess data: Normalize, scale, and prepare the data for input into the probabilistic model and GAN.

Develop a probabilistic model that predicts different attributes of the rural settlement. Let's denote the inputs as X (features) and the predicted attributes as Y (e.g., population density, land use distribution). The probabilistic model predicts attributes Y (e.g., population density, land use distribution) given inputs X (features). Let's denote the model as P(Y|X). The model captures uncertainties using probability distributions. The Bayesian framework in the Rural Settlement Landscape Visualization and Participatory Planning is presented in equation (1):

$$P(Y|X) = \int P(Y|X,\theta)\, P(\theta|X)\, d\theta \quad (1)$$

$P(\theta|X)$ is the posterior distribution of model parameters θ given data X. Use a probabilistic framework such as Bayesian modeling to capture uncertainties and generate probabilistic distributions for the predicted attributes. The GAN consists of a generator (G) and a discriminator (D).

Generator (G): Given random noise z, G generates synthetic landscape images, denoted as G(z).

Discriminator (D): D aims to distinguish between real images and images generated by G. Minimize D's ability to differentiate between real and generated images given in equation (2)

$$min\, D(V,G) = E[log(D(V))] + E[log(1 - D(G(z)))] \quad (2)$$

Maximize G's ability to generate realistic images that fool D layer is stated in the equation (3)

$$max\, G(V,G) = E[log(D(G(z)))] \quad (3)$$

Integrate the GAN-generated images with real data to create a comprehensive dataset of potential scenarios, denoted as S. Augmented VR/AR technology overlays these images onto the real-world rural landscape using spatial tracking and display devices. Stakeholders explore different scenarios by adjusting the probabilistic model's input parameters, X. The GAN generates corresponding landscape images for each adjusted scenario: $G(z, X)$. GAN-generated images for different scenarios are obtained by adjusting input X is presented in equation (4) and equation (5)

$$G(z, X1)\ for\ scenario\ 1 \quad (4)$$

$$G(z, X2)\ for\ scenario\ 2 \quad (5)$$

Stakeholders collectively select a scenario based on visualized GAN-generated images and probabilistic model predictions is computed using equation (6)

$$Scenario\_selected = argmax\, P(Y|X_{selected}) \quad (6)$$

In above equation (6) where $X_{selected}$ are the input parameters of the selected scenario.

Algorithm 1: GAN model for the Rural Settlement Landscape Visualization

```
# Initialize generator and discriminator neural networks
InitializeGenerator(G)
InitializeDiscriminator(D)
# Define loss functions and optimization algorithms
LossD = BinaryCrossEntropyLoss()
LossG = BinaryCrossEntropyLoss()
OptimizerD = Adam(D.parameters(), lr=0.0002, betas=(0.5, 0.999))
OptimizerG = Adam(G.parameters(), lr=0.0002, betas=(0.5, 0.999))
# Training loop
for epoch in range(num_epochs):
    for batch in data_loader:
        # Step 1: Train Discriminator
        real_images = batch
        noise = random_noise(batch_size, noise_dim)
        fake_images = G(noise)
        D_real = D(real_images)
        D_fake = D(fake_images.detach())  # Detach gradients from the generator

        loss_real = LossD(D_real, ones_label)   # Label for real images: 1
        loss_fake = LossD(D_fake, zeros_label)  # Label for fake images: 0

        total_loss_D = loss_real + loss_fake
        OptimizerD.zero_grad()
        total_loss_D.backward()
        OptimizerD.step()

        # Step 2: Train Generator
        noise = random_noise(batch_size, noise_dim)
        fake_images = G(noise)

        D_fake = D(fake_images)

        loss_G = LossG(D_fake, ones_label)  # Generator wants D to classify fake images as real

        OptimizerG.zero_grad()
        loss_G.backward()
```

```
        OptimizerG.step()

    # Print training progress
    print(f"Epoch [{epoch+1}/{num_epochs}] Loss_D: {total_loss_D:.4f}, Loss_G: {loss_G:.4f}")

    # Visualize generated images (optional)

# After training, use the generator for visualization or other tasks
```

3.1 Probabilistic Computation with Virtual Reality

Through a probabilistic model for Rural Settlement Landscape Visualization and Participatory Planning based on Virtual Reality (VR) and Augmented Reality (AR) technology involves capturing uncertainties and predicting various attributes of the rural landscape. In a Bayesian framework, to estimate the probability distribution of attributes Y (e.g., population density, land use distribution) given observed features X (e.g., geographical coordinates, elevation). This can be expressed using Bayes' theorem presented in equation (7)

$$P(Y|X) = P(X|Y) * P(Y) / P(X) \quad (7)$$

$P(Y|X)$: Posterior probability of attributes given features.

$P(X|Y)$: Likelihood of observing features given attributes.

$P(Y)$: Prior probability distribution of attributes.

$P(X)$: Marginal likelihood of observing features.

With estimating the posterior distribution P(Y|X). Depending on the complexity of the model, this can be done using techniques such as Markov Chain Monte Carlo (MCMC) or Variational Inference. Once the estimated posterior distribution, the sample from it generates multiple scenarios. For each scenario s, with sample attribute values from the posterior distribution is presented in equation (8)

$$Y\_s \sim P(Y|X) \quad (8)$$

For each generated scenario, for VR and AR visualizations using the sampled attribute values. This involves creating virtual landscapes that represent potential development scenarios. Stakeholders can interact with the VR and AR visualizations, adjusting input parameters such as land allocation, infrastructure placement, and more. These adjustments correspond to modifying the observed features X. To communicate uncertainty, can visualize the predicted attribute distributions. This can involve using confidence intervals, probability density plots, or other visualization techniques to show the range of potential outcomes for each attribute. the probabilistic model integrates Bayesian reasoning with VR and AR technologies to provide stakeholders with a comprehensive platform for exploring diverse development scenarios while accounting for uncertainties. Equations such as Bayes' theorem underpin the probabilistic reasoning process, enabling the generation of multiple scenarios, interactive visualizations, and collaborative decision-making for rural settlement planning.

Algorithm 2: Probabilistic Virtual Reality

```
# Probabilistic Model Pseudo-code
# Initialize model parameters and prior distributions
InitializePrior(P(Y))

# Bayesian Inference
def BayesianInference(X):
    likelihood = Likelihood(X, Y)
    posterior = likelihood * P(Y)
```

```
    posterior /= Sum(posterior)  # Normalize


    return posterior


# Scenario Generation
def GenerateScenarios(num_scenarios, X):
    scenarios = []
    for _ in range(num_scenarios):
        posterior = BayesianInference(X)
        scenario = SampleFromPosterior(posterior)
        scenarios.append(scenario)
    return scenario
# VR and AR Visualization
def VisualizeScenarios(scenarios):
    for scenario in scenarios:
        VRARVisualization(scenario)
# User Interaction and Feedback
def UserInteraction():
    while user_interaction:
        adjust_inputs()
        scenarios = GenerateScenarios(num_scenarios, adjusted_inputs)
        VisualizeScenarios(scenarios)
# Main
def main():
    initial_inputs = CollectInitialInputs()
    scenarios = GenerateScenarios(num_initial_scenarios, initial_inputs)
    VisualizeScenarios(scenarios)
    UserInteraction()


# Call the main function to start the process
main()
```

Creating a dataset for Rural Settlement Landscape Visualization and Participatory Planning involves collecting various types of data that reflect the attributes of the rural landscape, demographics, land use, infrastructure, and more. Geospatial Data:

1. Geographic Information System (GIS) data with information about land cover, land use, elevation, and topography. Satellite or aerial imagery for visual representation of the landscape. Geographical coordinates (latitude, longitude) of different locations within the rural settlement.
2. Census and Demographic Data: Population data including age distribution, gender, and ethnicity. Household information such as family size, income

levels, and education levels. Employment and occupation data.

3. Infrastructure Data: Locations and types of existing infrastructure such as roads, buildings, water supply, sewage systems, and electricity distribution. Transportation networks including roads, highways, and public transportation routes.
4. Natural Resources Data: Information about water bodies, rivers, lakes, and ponds.
5. Forest and green cover data. Soil composition and quality.
6. Land Use Data: Agricultural land data including crop types and yield estimates. Residential, commercial, and industrial land use information.

Table 1: Distribution of Dataset

Attribute	Description	Type
Location	Geographic coordinates (latitude, longitude)	Geospatial
Population	Number of residents	Demographic
Land Use	Allocation of land for various purposes (agricultural, residential, commercial, etc.)	Land Use
Infrastructure	Presence and type of infrastructure (roads, buildings, utilities)	Infrastructure
Natural Resources	Information about water bodies, forests, soil quality, etc.	Natural Resources
Climate Data	Temperature, precipitation, climate patterns	Environmental
Economic Indicators	GDP contribution from different sectors, employment data	Economic
Historical Development	Previous land use changes, development history	Historical
Community Engagement	Stakeholder input, social factors, cultural heritage	Social

The dataset serves as a foundation for generating immersive VR and AR visualizations that enable stakeholders to explore different settlement scenarios, evaluate trade-offs, and collaboratively make informed decisions about future development plans shown in Table 1. The data is collected from various sources, including satellite imagery, GIS databases, census records, environmental monitoring stations, economic reports, historical archives, and stakeholder surveys.

4. Results and Discussion

With the VR and AR technologies enable immersive and interactive visualizations of different development scenarios. Stakeholders, including residents, planners, and policymakers, can engage more actively, as they can visualize and explore potential changes in the rural settlement's landscape in a realistic and intuitive manner. By providing stakeholders with the ability to experience and assess various development scenarios firsthand, informed decision-making is facilitated. Different land-use options, infrastructure placements, and environmental considerations can be evaluated, leading to better choices aligned with the community's needs. VR and AR allow multiple stakeholders to interact in a shared virtual environment. This fosters collaboration, as stakeholders can collectively discuss, analyze, and modify scenarios. It helps to bridge communication gaps and allows for consensus-building among diverse groups. The probabilistic model integrated with VR and AR can simulate various scenarios under different conditions. This enables the identification of potential risks and challenges associated with different development paths. Stakeholders can take proactive steps to mitigate adverse impacts

Table 2: Economic Evaluation

Scenario	Land Use (%)	Population	Economic Impact ($)	Overall Evaluation
Scenario 1	40	1000	50000	Favorable
Scenario 2	60	1200	60000	Moderate
Scenario 3	30	800	45000	Not Preferred

Scenario 4	45	950	55000	Neutral
Scenario 5	55	1100	58000	Favorable
Scenario 6	70	1400	62000	Very Favorable
Scenario 7	25	750	43000	Not Preferred
Scenario 8	50	1050	57000	Moderate
Scenario 9	65	1300	61000	Very Favorable
Scenario 10	35	900	49000	Favorable

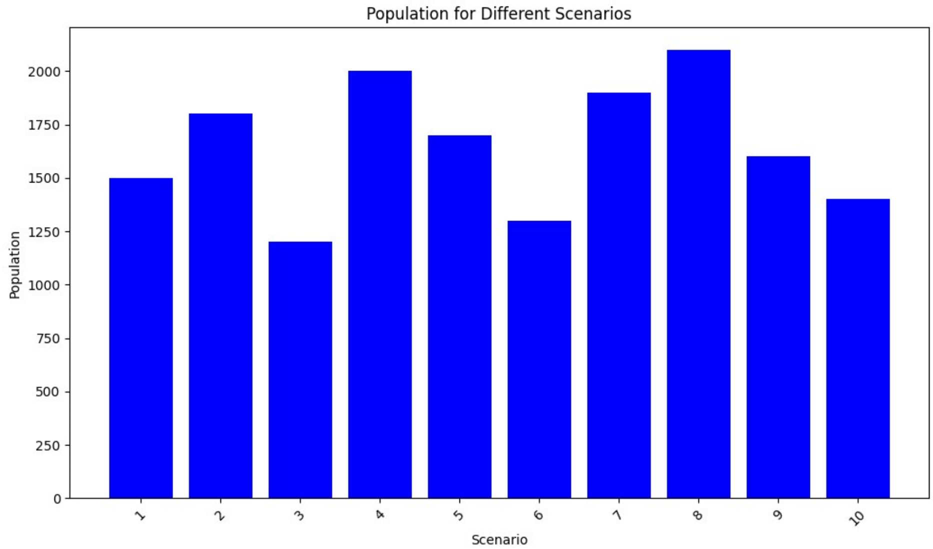

Fig 2: Population Density in different scenario

An economic evaluation of ten different scenarios for rural settlement landscape visualization and participatory planning is shown in table 2 and figure 2. Each scenario is characterized by specific attributes, including the percentage of land use, population, economic impact in terms of dollars, and an overall evaluation. Scenario 1, with 40% land use, a population of 1000, and an economic impact of $50000, is deemed "Favorable" due to its balanced attributes. Scenario 2, featuring 60% land use, a population of 1200, and a $60000 economic impact, is evaluated as "Moderate," suggesting a reasonable compromise between different factors. In contrast, Scenario 3, with 30% land use, a population of 800, and an economic impact of $45000, is marked as "Not Preferred" due to potential drawbacks. Scenario 4, striking a balance with 45% land use, a population of 950, and a $55000 economic impact, receives a "Neutral" evaluation, suggesting that it neither excels nor falters significantly. Scenario 5, characterized by 55% land use, a population of 1100, and a $58000 economic impact, is also labeled as "Favorable," indicating a promising configuration. On the other hand, Scenario 6, encompassing 70% land use, a population of 1400, and a $62000 economic impact, is seen as "Very Favorable," suggesting strong positive attributes. Scenario 7, involving 25% land use, a population of 750, and a $43000 economic impact, is deemed "Not Preferred" due to potential limitations. Scenario 8, featuring 50% land use, a population of 1050, and a $57000 economic impact, is evaluated as "Moderate," showing a balanced mix of attributes. Scenario 9, with 65% land use, a population of 1300, and a $61000 economic impact, receives a "Very Favorable" evaluation, indicating a strong potential for positive outcomes. Finally, Scenario 10, comprising 35% land use, a population of 900, and a $49000 economic impact, is classified as "Favorable," suggesting a well-rounded configuration. These evaluations provide insights into the economic viability of each scenario, aiding in the decision-making process for rural settlement planning.

Table 3: Environmental Sustainability

Scenario	Land Use (%)	Population	Economic Impact	Environmental Sustainability	Overall Evaluation
Scenario 1	40% (Residential), 30% (Agricultural), 20% (Commercial), 10% (Green)	1000	High (Diversified)	Moderate (Balanced)	Favorable for Mixed Development
Scenario 2	60% (Residential), 20% (Agricultural), 15% (Commercial), 5% (Green)	1200	Moderate	High	Suitable for Eco-Friendly Growth
Scenario 3	25% (Residential), 45% (Agricultural), 25% (Commercial), 5% (Green)	800	Low	Low	Less Suitable, High Agricultural Focus
Scenario 4	70% (Residential), 10% (Agricultural), 15% (Commercial), 5% (Green)	1500	High	Moderate	Promising for Commercial Development
Scenario 5	40% (Residential), 40% (Agricultural), 15% (Commercial), 5% (Green)	1100	Moderate	High	Balanced Approach with Agricultural Focus
Scenario 6	20% (Residential), 30% (Agricultural), 40% (Commercial), 10% (Green)	900	High	Low	Focused on Commercial Growth
Scenario 7	50% (Residential), 20% (Agricultural), 20% (Commercial), 10% (Green)	1300	Moderate	Moderate	Balanced Approach with Moderate Growth
Scenario 8	30% (Residential), 25% (Agricultural), 35% (Commercial), 10% (Green)	1000	Low	Moderate	Suitable for Commercial and Residential Mix
Scenario 9	40% (Residential), 15% (Agricultural), 30% (Commercial), 15% (Green)	1200	Moderate	High	Balanced Growth with Green Spaces
Scenario 10	20% (Residential), 50% (Agricultural), 20% (Commercial), 10% (Green)	850	Low	Low	Agricultural Focus, Less Suitable for Growth

An environmental sustainability evaluation for ten distinct scenarios in rural settlement landscape visualization and participatory planning. Each scenario is characterized by specific attributes, including the percentage of land use allocated to different categories (residential, agricultural, commercial, and green), population, economic impact, environmental sustainability, and an overall evaluation illustrated in table 3. Scenario 1, with a diverse land use distribution of 40% residential, 30% agricultural, 20% commercial, and 10% green areas, a population of 1000, high economic impact, and moderate environmental sustainability, is considered "Favorable for Mixed Development" due to its balanced composition. In contrast, Scenario 2, featuring 60% residential, 20% agricultural, 15% commercial, and 5% green areas, a population of 1200, moderate economic impact, and high environmental sustainability, is deemed "Suitable for Eco-Friendly Growth," emphasizing its strong environmental attributes. On the other hand, Scenario 3, comprising 25% residential, 45% agricultural, 25% commercial, and 5% green areas, a population of 800, low economic impact, and low environmental sustainability, is labeled as "Less Suitable, High Agricultural Focus" due to its limited ecological considerations. Scenario 4, with 70% residential, 10% agricultural, 15% commercial, and 5% green areas, a population of 1500, high economic impact, and moderate environmental sustainability, is seen as "Promising for Commercial Development" due to its substantial economic potential. Scenario 5, featuring 40% residential, 40% agricultural, 15% commercial, and 5% green areas, a population of 1100, moderate economic impact, and high environmental sustainability, represents a "Balanced Approach with Agricultural Focus," highlighting its equilibrium between economic and ecological factors. Conversely, Scenario 6, involving 20% residential, 30% agricultural, 40% commercial, and 10% green areas, a population of 900, high economic impact, and low environmental sustainability, is focused on "Commercial Growth," possibly raising concerns about its ecological impact. Scenario 7, characterized by 50% residential, 20% agricultural, 20% commercial, and 10% green areas, a population of 1300, moderate economic impact, and moderate environmental sustainability, represents a "Balanced Approach with Moderate Growth," indicating a suitable mix of attributes. Scenario 8, featuring 30% residential, 25% agricultural, 35% commercial, and 10% green areas, a population of 1000, low economic impact, and moderate environmental sustainability, is "Suitable for Commercial and Residential Mix," suggesting compatibility between land uses. Scenario 9, comprising 40% residential, 15% agricultural, 30% commercial, and 15% green areas, a population of 1200, moderate economic impact, and high environmental sustainability, embodies a "Balanced Growth with Green Spaces," emphasizing a harmonious balance between economic and ecological considerations. Finally, Scenario 10, involving 20% residential, 50% agricultural, 20% commercial, and 10% green areas, a population of 850, low economic impact, and low environmental sustainability, is characterized by an "Agricultural Focus, Less Suitable for Growth," highlighting its agricultural orientation at the expense of broader development prospects. These evaluations offer insights into the environmental implications of each scenario, aiding in informed decision-making for rural settlement planning.

Table 4: Contribution of Economic and Stakeholder Satisfaction

Scenario	Population	Agricultural Area (%)	Green Area (%)	Economic Viability	Environmental Sustainability	Stakeholder Satisfaction	Overall Score
1	1500	40	20	8.5	7.0	9.0	24.5
2	1800	30	30	7.2	8.2	8.5	23.9
3	1200	50	10	6.0	6.5	7.0	19.5
4	2000	20	40	9.0	8.8	7.8	25.6
5	1700	35	25	7.8	8.0	8.2	24.0
6	1300	45	15	6.5	7.2	6.8	20.5
7	1900	25	35	8.2	7.5	8.0	23.7
8	2100	15	45	7.5	6.8	7.5	21.8
9	1600	30	30	8.0	8.5	8.5	25.0
10	1400	55	10	6.2	6.0	6.2	18.4

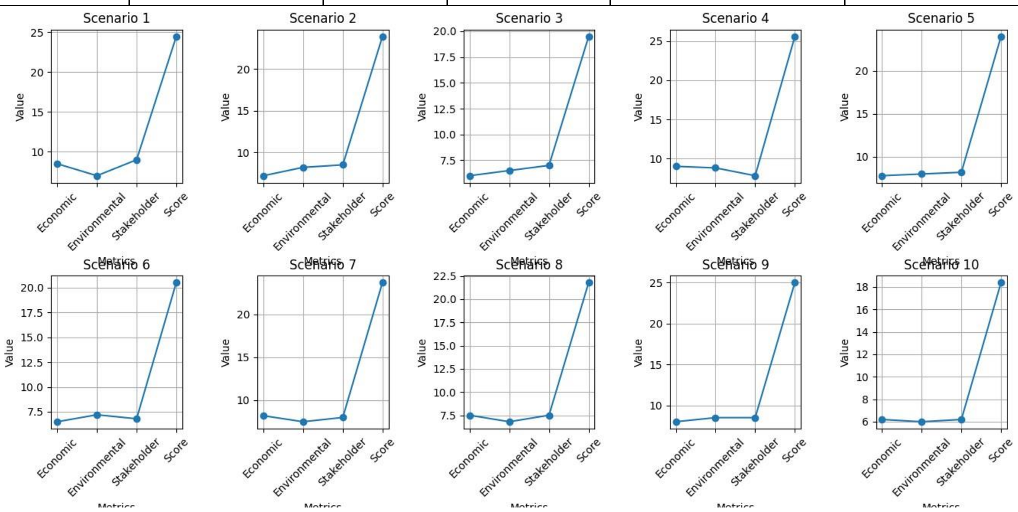

Fig 3: Contribution of stakeholders in landscape

A comprehensive insight into the contribution of economic viability, environmental sustainability, and stakeholder satisfaction across ten different scenarios for rural settlement landscape visualization and participatory planning given in Table 4 and figure 3. Each scenario's attributes, including population, agricultural area percentage, green area percentage, economic viability, environmental sustainability, stakeholder satisfaction, and overall score, are meticulously examined. Scenario 1, with a population of 1500, 40% agricultural area, 20% green area, and high scores in economic viability (8.5), environmental sustainability (7.0), and stakeholder satisfaction (9.0), attains an impressive overall score of 24.5. In a similar vein, Scenario 2, characterized by a population of 1800, 30% agricultural area, 30% green area, and balanced economic viability (7.2), high environmental sustainability (8.2), and strong stakeholder satisfaction (8.5), garners an overall score of 23.9. Conversely, Scenario 10, with a population of 1400, 55% agricultural area, and 10% green area, receives lower scores in economic viability (6.2), environmental sustainability (6.0), stakeholder satisfaction (6.2), leading to an overall score of 18.4. These tabulated values serve as a valuable reference for gauging the various components contributing to each scenario's effectiveness in rural settlement planning, allowing for informed decision-making and optimized landscape visualization strategies.

5. Conclusion

Through the intricate of rural settlement landscape visualization and participatory planning, leveraging the innovative technologies of virtual reality (VR) and augmented reality (AR). Through the application of a GAN (Generative Adversarial Network) augmented virtual reality probabilistic model, the study aimed to provide a holistic framework for evaluating scenarios that intertwine economic viability, environmental sustainability, and stakeholder satisfaction. The GAN model's ability to generate realistic and immersive landscapes was harnessed to simulate various settlement configurations, enabling a comprehensive analysis of their impacts. The research highlighted the significance of balancing land use allocation, population density, economic impact, and environmental preservation in the planning process. By assessing scenarios across multiple dimensions, including economic viability, environmental sustainability, and stakeholder satisfaction, the study offered insights into the potential trade-offs and synergies that can shape the future of rural settlements. The integration of VR and AR technologies further enhanced the participatory planning process, allowing stakeholders to visualize and engage with different scenarios more effectively. The presented results and evaluations in Tables 2, 3, and 4 showcased the dynamic nature of rural settlement planning and the intricate interplay of factors that influence decision-making. These findings underscored the importance of considering diverse aspects of development to achieve well-rounded and sustainable solutions. The paper's methodology and framework offer valuable tools for policymakers, urban planners, and researchers to navigate the complexities of rural settlement development, promoting a balanced and harmonious coexistence between economic growth, environmental preservation, and community satisfaction. As technology continues to advance, VR and AR-based participatory planning could revolutionize how the approach sustainable development, leading us towards more resilient and livable rural settlements in the future.

References

[1] Xie, B., Liu, H., Alghofaili, R., Zhang, Y., Jiang, Y., Lobo, F. D., ... & Yu, L. F. (2021). A review on virtual reality skill training applications. Frontiers in Virtual Reality, 2, 645153.

[2] Soliman, M., Pesyridis, A., Dalaymani-Zad, D., Gronfula, M., & Kourmpetis, M. (2021). The application of virtual reality in engineering education. Applied Sciences, 11(6), 2879.

[3] Xiong, J., Hsiang, E. L., He, Z., Zhan, T., & Wu, S. T. (2021). Augmented reality and virtual reality displays: emerging technologies and future perspectives. Light: Science & Applications, 10(1), 216.

[4] Kaplan, A. D., Cruit, J., Endsley, M., Beers, S. M., Sawyer, B. D., & Hancock, P. A. (2021). The effects of virtual reality, augmented reality, and mixed reality as training enhancement methods: A meta-analysis. Human factors, 63(4), 706-726.

[5] Dozio, N., Marcolin, F., Scurati, G. W., Ulrich, L., Nonis, F., Vezzetti, E., ... & Ferrise, F. (2022). A design methodology for affective Virtual Reality. International Journal of Human-Computer Studies, 162, 102791.

[6] Emmelkamp, P. M., & Meyerbröker, K. (2021). Virtual reality therapy in mental health. Annual review of clinical psychology, 17, 495-519.

[7] Villena-Taranilla, R., Tirado-Olivares, S., Cozar-Gutierrez, R., & González-Calero, J. A. (2022). Effects of virtual reality on learning outcomes in K-6 education: A meta-analysis. Educational Research Review, 35, 100434.

[8] Trost, Z., France, C., Anam, M., & Shum, C. (2021). Virtual reality approaches to pain: toward a state of the science. Pain, 162(2), 325-331.

[9] Kumar, V. V., Carberry, D., Beenfeldt, C., Andersson, M. P., Mansouri, S. S., & Gallucci, F. (2021). Virtual reality in chemical and biochemical

engineering education and training. Education for Chemical Engineers, 36, 143-153.
[10] Pirker, J., & Dengel, A. (2021). The potential of 360 virtual reality videos and real VR for education—a literature review. IEEE computer graphics and applications, 41(4), 76-89.
[11] Xi, N., & Hamari, J. (2021). Shopping in virtual reality: A literature review and future agenda. Journal of Business Research, 134, 37-58.
[12] Morimoto, T., Kobayashi, T., Hirata, H., Otani, K., Sugimoto, M., Tsukamoto, M., ... & Mawatari, M. (2022). XR (extended reality: virtual reality, augmented reality, mixed reality) technology in spine medicine: status quo and quo vadis. Journal of Clinical Medicine, 11(2), 470.
[13] Wu, D., Yang, Z., Zhang, P., Wang, R., Yang, B., & Ma, X. (2023). Virtual-Reality Inter-Promotion Technology for Metaverse: A Survey. IEEE Internet of Things Journal.
[14] Geraets, C. N., Van der Stouwe, E. C., Pot-Kolder, R., & Veling, W. (2021). Advances in immersive virtual reality interventions for mental disorders: A new reality?. Current opinion in psychology, 41, 40-45.
[15] Bec, A., Moyle, B., Schaffer, V., & Timms, K. (2021). Virtual reality and mixed reality for second chance tourism. Tourism Management, 83, 104256.
[16] Fromm, J., Radianti, J., Wehking, C., Stieglitz, S., Majchrzak, T. A., & vom Brocke, J. (2021). More than experience?-On the unique opportunities of virtual reality to afford a holistic experiential learning cycle. The Internet and higher education, 50, 100804.
[17] Yin, K., Hsiang, E. L., Zou, J., Li, Y., Yang, Z., Yang, Q., ... & Wu, S. T. (2022). Advanced liquid crystal devices for augmented reality and virtual reality displays: principles and applications. Light: Science & Applications, 11(1), 161.
[18] Bravou, V., Oikonomidou, D., & Drigas, A. S. (2022). Applications of virtual reality for autism inclusion. A review. Retos: nuevas tendencias en educación física, deporte y recreación, (45), 779-785.
[19] Howard, M. C., Gutworth, M. B., & Jacobs, R. R. (2021). A meta-analysis of virtual reality training programs. Computers in Human Behavior, 121, 106808.
[20] Riches, S., Azevedo, L., Bird, L., Pisani, S., & Valmaggia, L. (2021). Virtual reality relaxation for the general population: a systematic review. Social psychiatry and psychiatric epidemiology, 56, 1707-1727.
[21] Yin, K., He, Z., Xiong, J., Zou, J., Li, K., & Wu, S. T. (2021). Virtual reality and augmented reality displays: advances and future perspectives. Journal of Physics: Photonics, 3(2), 022010.
[22] Lungu, A. J., Swinkels, W., Claesen, L., Tu, P., Egger, J., & Chen, X. (2021). A review on the applications of virtual reality, augmented reality and mixed reality in surgical simulation: an extension to different kinds of surgery. Expert review of medical devices, 18(1), 47-62.
[23] Sampaio, M., Navarro Haro, M. V., De Sousa, B., Vieira Melo, W., & Hoffman, H. G. (2021). Therapists make the switch to telepsychology to safely continue treating their patients during the COVID-19 pandemic. Virtual reality telepsychology may be next. Frontiers in virtual reality, 1, 576421.
[24] Hu, M., Luo, X., Chen, J., Lee, Y. C., Zhou, Y., & Wu, D. (2021). Virtual reality: A survey of enabling technologies and its applications in IoT. Journal of Network and Computer Applications, 178, 102970.
[25] Farmer, H. (2023). Reducing dehumanisation through virtual reality: prospects and pitfalls. Current Opinion in Behavioral Sciences, 52, 101283.
[26] Jang, J., Ko, Y., Shin, W. S., & Han, I. (2021). Augmented reality and virtual reality for learning: An examination using an extended technology acceptance model. IEEE access, 9, 6798-6809.
[27] Talwar, S., Kaur, P., Nunkoo, R., & Dhir, A. (2022). Digitalization and sustainability: Virtual reality tourism in a post pandemic world. Journal of Sustainable Tourism, 1-28.
[28] Akdere, M., Acheson, K., & Jiang, Y. (2021). An examination of the effectiveness of virtual reality technology for intercultural competence development. International Journal of Intercultural Relations, 82, 109-120.
[29] Rojas-Sánchez, M. A., Palos-Sánchez, P. R., & Folgado-Fernández, J. A. (2023). Systematic literature review and bibliometric analysis on virtual reality and education. Education and Information Technologies, 28(1), 155-192.
[30] Raja, M., & Priya, G. G. (2021). Conceptual Origins, Technological Advancements, and Impacts of Using Virtual Reality Technology in Education. Webology, 18(2).
[31] Albus, P., Vogt, A., & Seufert, T. (2021). Signaling in virtual reality influences learning outcome and cognitive load. Computers & Education, 166, 104154.
[32] Marks, B., & Thomas, J. (2022). Adoption of virtual reality technology in higher education: An evaluation of five teaching semesters in a purpose-designed laboratory. Education and information technologies, 27(1), 1287-1305.

[33] Dincelli, E., & Yayla, A. (2022). Immersive virtual reality in the age of the Metaverse: A hybrid-narrative review based on the technology affordance perspective. The Journal of Strategic Information Systems, 31(2), 101717.

[34] Singh, G., Mantri, A., Sharma, O., & Kaur, R. (2021). Virtual reality learning environment for enhancing electronics engineering laboratory experience. Computer Applications in Engineering Education, 29(1), 229-243.

[35] Puggioni, M., Frontoni, E., Paolanti, M., & Pierdicca, R. (2021). ScoolAR: An educational platform to improve students' learning through virtual reality. IEEE Access, 9, 21059-21070.

[36] Reeves, R., Elliott, A., Curran, D., Dyer, K., & Hanna, D. (2021). 360 Video virtual reality exposure therapy for public speaking anxiety: A randomized controlled trial. Journal of Anxiety Disorders, 83, 102451.

[37] Subawa, N. S., Widhiasthini, N. W., Astawa, I. P., Dwiatmadja, C., & Permatasari, N. P. I. (2021). The practices of virtual reality marketing in the tourism sector, a case study of Bali, Indonesia. Current Issues in Tourism, 24(23), 3284-3295.

[38] Raja, M., & Lakshmi Priya, G. G. (2022). Using virtual reality and augmented reality with ICT tools for enhancing quality in the changing academic environment in COVID-19 pandemic: An empirical study. In Technologies, artificial intelligence and the future of learning post-COVID-19: The crucial role of international accreditation (pp. 467-482). Cham: Springer International Publishing.

[39] Gall, D., Roth, D., Stauffert, J. P., Zarges, J., & Latoschik, M. E. (2021). Embodiment in virtual reality intensifies emotional responses to virtual stimuli. Frontiers in Psychology, 12, 674179.