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RESEARCH ARTICLE

The Analysis of Artificial Intelligence Digital Technology in Art Education Under the Internet of Things

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ABSTRACT This study aims to explore the integration of Internet of Things (IoT) technology and artificial intelligence (AI) in art education, assessing its impact on learners' experiences and learning outcomes. The study first proposes a digital teaching system that enables the IoT and Generative Adversarial Networks (GANs) to play a role in art education by monitoring students' creative state in real-time, providing immediate feedback, and facilitating the generation of creative works. The system framework includes sensor nodes, an IoT platform, a GAN model, and a user interface to build a real-time interactive environment. Sensor nodes constantly collect physiological, movement, and environmental data from students, and the GAN model receives student data from the IoT platform, combining creative input from students to generate artwork in real-time. The generated works are transmitted to the discriminator through the IoT platform, which evaluates their quality and provides real-time feedback. Students interact with the system through the user interface, observe the generated artwork, adjust generator parameters, and propose new ideas. These interactions influence further artistic creation. The WikiArt public art creation dataset is selected to establish the experimental foundation, and the experimental evaluation focuses on image generation quality, system performance, and student learning outcomes. It is compared with Deep Convolutional Generative Adversarial Network (DCGAN) and Variational Autoencoder (VAE) models. The research results indicate that the designed IoT and GANs integrated system remarkably outperforms DCGAN and VAE in image generation quality, with an Inception Score of 4.5, which is more diverse and recognizable than other models. Regarding system performance, the IoT and GANs integrated system is significantly ahead in image generation speed and user interaction, with a transmission speed of up to 200 Mbps. Regarding student learning outcomes, the system performs excellently in emotional feedback, learning outcomes, and creative work quality, achieving 80% satisfaction and 90% positive feedback. Overall, the research conclusion clearly points out that the integration of IoT and GANs has a significant and comprehensive effect on improving the quality of art education. This study expands the field of art education by integrating IoT and GANs, enhancing students' creative experiences, and providing innovative methods for art teaching in the digital age.

INDEX TERMS Internet of Things technology, generative adversarial network, art education, digital teaching.

I. INTRODUCTION

A. RESEARCH BACKGROUND AND MOTIVATIONS

With the rapid development of technology, the integration of the Internet of Things (IoT) and artificial intelligence (AI) has become a key driving force for transformation across various industries [1], [2], [3]. In the wake of this trend, the field of education is undergoing profound changes, presenting new opportunities for fostering students' comprehensive abilities and innovative thinking [4], [5]. As an essential component for cultivating students' aesthetic emotions and creative capabilities, art education naturally should fully leverage these

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emerging technologies to make teaching more dynamic and responsive to students' needs [6], [7], [8].

In the past few years, the rise of digital technology has caused a radical change in the education domain. Especially in art teaching, traditional teaching methods and media can no longer meet the needs of today's students. As a bridge between the physical and digital worlds, IoT technology offers unprecedented opportunities for arts education. Integrating IoT technology and AI has become the key to innovation in art education. By monitoring the creative status of students in real-time, offering immediate feedback, and promoting the generation of creative works, the constraints of traditional teaching can be broken, creating a more interactive and personalized learning experience. Students in the digital age expect to experience the integration of advanced technology in their learning, making people rethink art education methods and means. In addition, in traditional art education, students typically rely on static learning materials and conventional teaching methods, which, to some extent, limit creative space and instructional interactivity [9], [10], [11]. However, the gradual maturity of IoT technology allows humanity to inject new vitality into art education by connecting various devices and employing innovative digital means [12], [13], [14]. This raises a crucial question: under the guidance of the IoT, how can this study fully harness the advantages of AI digital technology to serve the teaching and creative processes in art education [15], [16], [17]. The design of a digital teaching system is to explore the best integration of IoT technology and AI in art education. The system provides students with a real-time and personalized art learning experience through the collaborative effect of sensor nodes, IoT platforms, and GAN models. This helps stimulate students' creativity and enhances their learning effectiveness. In this digital era, it is believed that integrating IoT technology and AI into art education can create a richer and deeper learning experience for students and inject new vitality into art teaching. This study aims to explore this integration's practical effects, providing innovative directions for future arts education.

As students become increasingly familiar with digital technology, integrating IoT and AI technologies becomes a unique pathway to enhance the quality and creativity of art education [18], [19], [20]. Innovative digital technologies can provide students with more interactive and real-time feedback-oriented learning experiences, driving breakthroughs and individual development in their artistic creations [21], [22].

B. RESEARCH OBJECTIVES

The core objective of this study is to delve into the innovative application of Generative Adversarial Networks (GANs) in art education under the guidance of the IoT. The specific goals aim to address the following key questions and achieve tangible outcomes: Investigate how GANs can be utilized to generate more artistic and creative works of art, expanding students' artistic creative space. Exploring how IoT technology can seamlessly integrate with GANs to create a more interactive and real-time art education experience. Conduct empirical research to assess the application effectiveness of GANs in art education, including improvements in student creative outputs, learning experiences, and teaching effectiveness. The attainment of these specific objectives is designed to offer practical and feasible solutions for introducing innovative technologies into art education, enhancing teaching quality, and stimulating students' creativity [23], [24], [25].

C. RESEARCH CONTRIBUTIONS

This study has made many contributions to the field of art education. First, the research proposes and designs an innovative digital teaching system integrating IoT technology and GANs into art education. By monitoring the creative status of students in real-time, giving immediate feedback, and enhancing the generation of creative works, this system introduces new teaching methods for art education and enriches traditional teaching methods. Second, this study has achieved breakthroughs in constructing the system framework. A real-time interactive environment has been built by combining GAN models, IoT platforms, sensor nodes, and user interfaces, providing students with a more immersive and personalized learning experience. The innovation of this system framework improves teaching effectiveness and provides useful experience for designing future digital education systems. Third, the study has unique characteristics in experimental design and data selection. The study demonstrates depth and comprehensiveness at the experimental level by selecting public art creation datasets such as WikiArt and Abstract Art and paying close attention to image generation quality, system performance, and student learning outcomes. Compared with traditional models such as DCGAN and VAE, the research results show dominant advantages of IoT and GAN integrated systems in image generation quality, introducing advanced technological means for art education. In addition, this study has made significant contributions to system performance. The IoT and GANs integrated system demonstrates higher practicality and user-friendliness by demonstrating superior image generation speed and user interaction performance. The system transmission speed reaches 200 Mbps, thus ensuring that students can smoothly participate in artistic creation and learning processes in a digital environment. Most importantly, by comprehensively evaluating students' emotional feedback, learning outcomes, and creative work quality, the study has demonstrated the IoT and GANs integrated system's excellent performance in improving the quality of art education. Obtaining 80% satisfaction and 90% positive feedback can prove the successful application of the system and strengthen its effectiveness in stimulating students' creative thinking and improving learning outcomes. In summary, the contribution of this study lies in introducing advanced digital technology into art education, designing a new teaching system framework, and demonstrating apparent advantages in image generation, performance, and student learning outcomes through experiments. This provides an innovative path and practical experience for developing art education in the future digital age.

II. LITERATURE REVIEW

In art education, research on technological integration has yielded a series of noteworthy achievements [26], [27], [28]. For instance, Song and Lim [29] investigated how two teachers utilized teaching methods and technology and how their students responded to their instructional efforts. Li [30], from both teacher and student perspectives, conducted a multidimensional analysis to identify factors influencing the effectiveness of classroom teaching in professional art education. West and Bautista [31] applied a systematic concept to the professional development of music and art teachers, viewing policy as a systemic issue to address longstanding accessibility and scalability problems. Through an art education program, Vazquez-Marin et al. [32] demonstrated that the relationships between key abilities act as catalysts for developing students' character strengths. Hwang et al. [33] proposed a two-tiered testing method based on digital games, providing students with a more engaging way to learn art and explore world-renowned masterpieces in the context of gaming. Rihter et al. [34] analyzed self-assessments by art teachers in Slovenian primary and secondary schools regarding their ability to collaborate with students with special educational needs.

In the past decade, with the swift growth of digital technology, art education has also undergone profound changes. Relevant scholars have conducted extensive research on the application of IoT technology and AI in art education, which affords theoretical solid support for this study. For example, Dec et al. pointed out that introducing IoT technology brought new possibilities to art education [35]. By using sensors during the student creative process, teachers can monitor their creative status in real-time, thereby better understanding their learning needs and providing personalized guidance. Wang et al. conducted an in-depth study on the role of AI in artistic creation [36]. They emphasized the potential of GANs in art generation, promoting the emergence of creativity through interaction between students and intelligent systems. Paś Ko et al. focused on the impact of digital technology on traditional art teaching methods [37]. He pointed out that students in the digital age were more inclined to learn through interaction with advanced technologies, posing a challenge to traditional teaching methods. In a comparative study, Lyu et al. explored the effects of different digital teaching systems. They found that systems that integrate IoT technology and AI performed excellently in enhancing students' creative experiences and learning outcomes [38]. Ma et al. focused their research on the changing expectations of students towards art teaching in the digital age, emphasizing the necessity of integrating advanced technologies [39]. Wang et al. focused on the application of digital technology in art education and proposed suggestions for integrating virtual reality (VR) and other technologies in teaching [40]. Matthew et al. explored the influence of digital technology on the transmission of knowledge in the art discipline, providing a new perspective on teaching methods [41]. Ahmad et al. studied the application of big data in art education and proposed the possibility of personalized teaching, advocating for the intelligent application of digital means [42]. Zeeshan et al. focused on the practical application of digital technology in art teaching, emphasizing the benefits of student participation in digital creation [43]. Stadnicka et al. provided practical case studies and data support through empirical research on students using IoT technology to learn art [44]. In summary, the research of these scholars offered a strong theoretical basis for this study, supporting the innovative application of integrating IoT technology and AI in art education.

While research on technological integration in art education and discussions on digital trends have made significant progress, there is a relative lack of studies on applying GANs under the guidance of the IoT in art education. Therefore, this study aims to fill this gap by thoroughly investigating the application of GANs under IoT guidance in art education, exploring the synergies between the two, and achieving more creative and interactive art teaching. Through the design and implementation of empirical research, this study assesses the practical effects of GANs in art education, providing educators with viable teaching support and creative tools, thus addressing the existing research gap.

III. RESEARCH MODEL

A. APPLICATION RESEARCH OF AI DIGITAL TECHNOLOGY IN ART EDUCATION

Art education is undergoing significant transformation in the digital era, with the emergence of AI digital technology opening up new possibilities in this field [45], [46], [47]. Figure 1 illustrates the application of AI digital technology in art education:

Figure 1 reveals the application scenarios of online teaching platforms, virtual art galleries, and intelligent assistive creation tools. On one hand, digital technology offers a new teaching platform for art education. Through online platforms, students can access rich learning resources anytime, anywhere, while teachers can better interact with students through real-time engagement. On the other hand, VR technology provides students with artistic experiences that cannot be obtained in traditional classrooms. Students can immerse themselves in the artistic charm of famous paintings through virtual art galleries, gaining a deeper understanding of works from different artistic styles and periods, thereby expanding their aesthetic perspectives.

Simultaneously, intelligent assistive creation tools analyze students' creative processes and works, offering real-time suggestions and feedback to help them overcome challenges in their creation and stimulate more creative thinking.

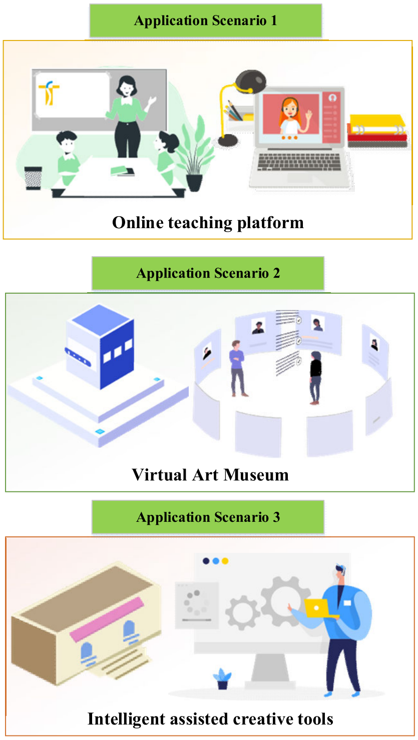

FIGURE 1. Application of AI digital technology in art education.

In-depth research on the application of AI digital technology in art education affords a clear background and foundation for the subsequent integration of GANs and IoT technologies.

B. SELECTION OF THE GAN MODEL

To propel the digital transformation of art education, GANs are chosen as the research model [48], [49], [50]. This study selects GANs as the research model. GANs consist of a generator and a discriminator, which enable the generator to generate realistic artworks through adversarial training, while the discriminator evaluates whether the generated works are similar to real works. GANs are chosen because of their widespread application and success in image generation tasks. The strength of GAN models lies in their ability to learn and generate high-quality and realistic images, which is particularly important for creative generation tasks in art education [51], [52], [53]. The generator takes a random vector z, often called noise in latent space, and maps it to the data space through a deep neural network, generating an image estimated to be a real artwork. The generator's objective is to deceive the discriminator, making it unable to distinguish between the generated and real works. The generator can be mathematically represented as the function G:z→x, where z is the input random vector, and x is the generated image.

The discriminator takes an image as input and outputs a probability value between 0 and 1, indicating the probability that the input image is a real artwork. The discriminator's goal is to accurately differentiate between the works generated by the generator and real works. Mathematically, the discriminator can be represented as the function $G : x \rightarrow [0, 1]$, where x is the input image, and the function output represents the probability that the input image is a real artwork. In the training process, the generator and discriminator engage in adversarial training. The generator attempts to produce realistic works, while the discriminator aims to distinguish between generated and real works accurately. This competition is achieved by minimizing the loss functions of the generator and discriminator, as shown in Eq. (1):

$$\min_{G} \max_{D} V(D, G) = \mathbb{E}_{x\sim p_{data}(x)}[logD(x)] + \mathbb{E}_{z\sim p_{Z}(z)}[log(1 - D(G(z)))] \quad (1)$$

Eq. (1) reflects the adversarial training between the generator and discriminator. $p_{\text{data}}(x)$ represents the distribution of real data, and $p_z(z)$ represents the noise distribution input to the generator. This adversarial training mechanism continuously enhances the generator's ability to produce realistic works, while the discriminator continually optimizes to discern real and generated works more accurately. Figure 2 displays the application scenarios of GANs in art education:

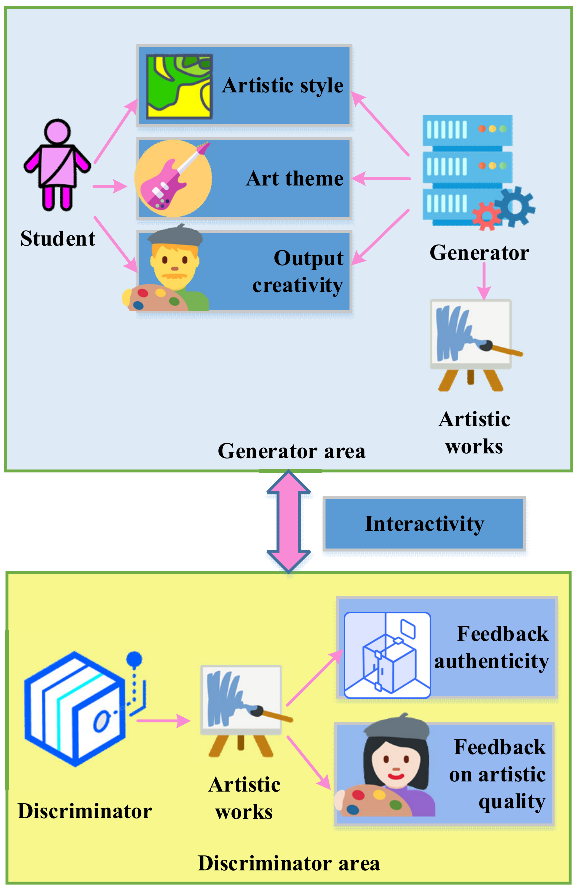

FIGURE 2. Application scenarios of GANs in art education.

In Figure 2, GANs exhibit diverse application scenarios in art education. On the one hand, GANs can learn and apply artists' painting styles, enabling students to create various styles. By training the generator to mimic different artists' styles, students can experience diverse artistic expressions in their works. On the other hand, learning from a vast array of artworks allows GANs to be powerful assistants for student creations. Students' creative inputs guide the generator, generating creative suggestions and providing students with novel ideas and artistic elements. This creative generation mechanism inspires students, encouraging them to be bolder and more innovative in their artistic endeavors.

Combining IoT technology, GANs can achieve real-time interaction and adjust the generation process based on student feedback. This interactive mechanism allows students to experience the generator's feedback in real-time during the creative process, enabling adjustments based on individual preferences. Through real-time interaction with the system, students gain a deeper understanding of the artistic creation process and produce works that better align with personalized requirements.

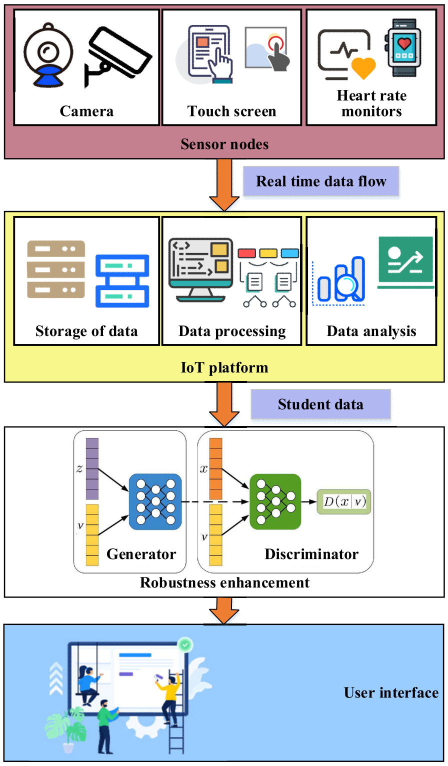

FIGURE 3. System framework integrating IoT and GANs for art education.

C. INTEGRATION OF IOT TECHNOLOGY AND GANS FOR ART EDUCATION

To further enrich the digital learning experience in art education, this study integrates IoT technology with GANs, constructing an innovative system framework to provide a more intelligent and personalized art teaching environment. By learning the styles and characteristics of artworks through the GANs training generator, GANs can provide students with various artistic expressions. At the same time, through integrating IoT technology, GANs can generate personalized artworks in real-time interaction. Adjustments are made based on the creative input of students, resulting in a more intelligent and personalized art learning experience. Overall, the choice of GAN architecture is to fully leverage its outstanding performance in the field of image generation and offer more advanced and personalized solutions for art education by integrating IoT technology. Figure 3 depicts the specific content of the system framework:

In Figure 3, the framework is divided into four main components:

1) Sensor Nodes

Sensor nodes capture multidimensional information about students' creative processes through various sensor devices, such as cameras, touchscreens, heart rate monitors, etc. These sensor nodes are positioned in the student's workspace, continuously collecting real-time data on the student's physiological state, movement feedback, and surrounding environmental information.

2) The IoT Platform

The IoT platform serves as a centralized data processing and transmission center. It receives real-time data streams from sensor nodes and is responsible for data storage, processing, and analysis. The platform uses IoT technology to ensure sensor data's rapid transmission and real-time availability.

3) The GAN Model

The GAN model receives student data from the IoT platform, including physiological information, movement feedback, and environmental data. Through adversarial training, the generator generates art pieces in real-time based on the student's creative input, while the discriminator evaluates the quality of the generated works.

4) User Interface

The user interface is the window through which students interact with the system. It provides an intuitive platform, allowing students to adjust generator parameters through touchscreens or other interactive devices, observe generated artworks, and receive real-time feedback from the discriminator. The user interface enables students to understand their creative states and actively participate in the generation process of artistic works. The basic workflow of the system is illustrated in Figure 4:

In Figure 4, the basic workflow of the system is as follows:

1) Data Collection and Transmission: Sensor nodes continuously collect physiological, movement, and environmental data from students in real-time, transmitting this data to the IoT platform.

2) Real-time Monitoring and Analysis: The IoT platform receives and stores data from sensor nodes, monitors students' creative states in real-time, analyzes sensor data, and extracts key information. This information covers students' physiological reactions, movement characteristics, and the influence of the surrounding environment.

3) GANs Generation: The IoT platform transmits the extracted key information to the GAN model. The GAN model receives this data, combines it with the student's

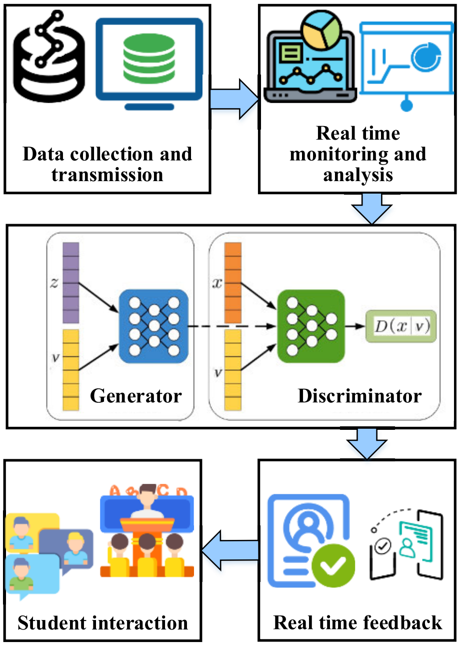

FIGURE 4. System workflow.

creative input, and generates adaptive and creative artworks in real-time. The generator continuously produces new work while maintaining interaction with the student.

4) Real-time Feedback: The generated artworks are transmitted to the discriminator through the IoT platform. The discriminator assesses the quality of the generated works and provides real-time feedback. This feedback involves evaluations of the authenticity and artistic qualities of the artworks.

5) Student Interaction: Students can interact with the system through the user interface. They can observe the generated artwork and real-time feedback from the discriminator, adjust creative parameters, and propose new ideas. These student interactions are transmitted through the user interface to the GAN model, influencing further creative output from the generator.

This study leverages IoT technology to enhance real-time monitoring, data transmission, and personalized learning experiences in arts education. It selects various sensor devices, including cameras, touch screens, heart rate monitors, etc., to capture multidimensional information in students' creative process. These sensor nodes are strategically placed in the student's work area to ensure continuous real-time physiological, motor, and environmental data collection. Sensor nodes use IoT technology to transmit real-time data collected to the IoT platform. The data collection process includes continuously monitoring students' physiological state, exercise feedback, and information about the surrounding environment. IoT technology ensures fast transmission and real-time data performance, supporting subsequent analysis and generation. The study designs a centralized IoT platform that receives, stores, processes, and analyzes data from sensor nodes. The platform has efficient data management functions to ensure that all kinds of information generated in students' creative process can be recorded and analyzed in a timely manner. The IoT platform provides input data for subsequent GAN models, enabling real-time artwork generation. The IoT platform passes the student data collected in real-time to the GAN model, encompassing physiological information, movement feedback, and environmental data. During GANs' adversarial training, the generator generates artworks in real time based on students' creative input and IoT-transmitted data, while the discriminator assesses the quality of these works. This integrated approach allows the generated artwork to be adapted to the student's actual state and creative needs, furnishing a more intelligent and personalized art learning experience. In the above ways, the organic integration of IoT technology and GANs brings a higher level of real-time monitoring and personalized learning experience to art education, providing students with a more creative and interactive art learning environment.

IV. EXPERIMENTAL DESIGN AND PERFORMANCE EVALUATION

A. DATASETS COLLECTION

This study chose publicly available art creation datasets to establish a robust experimental foundation. Among them, the WikiArt dataset is an online platform containing many artworks, offering pieces from different artists and periods [54]. Download address for WikiArt dataset: https://aistudio.baidu.com/datasetdetail/222219. The experiment selected works from various genres and themes within WikiArt. The Abstract Art dataset specifically focuses on abstract art, featuring works from artists associated with the abstract movement [55]. This study introduces this dataset to emphasize exploring the GAN performance in generating abstract art styles. Combining these publicly available datasets ensures that the GAN model can learn and generate diverse art pieces covering different genres, themes, and artistic styles.

B. EXPERIMENTAL ENVIRONMENT

Table 1 summarizes the critical software and tools used in the experimental environment:

C. PARAMETERS SETTING

A series of parameter adjustments are performed in the experiment to optimize the performance of the GAN model. Table 2 summarizes the key parameters used in the experiments and their settings:

D. PERFORMANCE EVALUATION

To comprehensively assess the performance of the IoT and GANs integrated system, three metrics were selected for evaluating the quality of generated images: Inception Score (IS), Frechet Inception Distance (FID), and Structural

TABLE 1. Experimental environment configuration.

SOFTWARE/TOOLS	Purpose
TensorFlow and PyTorch	Deep learning frameworks: Used for constructing and training GAN models.
Unity 3D	Game engines: Employed to create virtual art classroom environments.
Blender	3D modeling software: Utilized for designing environmental elements within the virtual art classroom.
Python	Primary programming languages: Applied for experimental script writing, data processing, and system integration.
IoT simulation tools (Contiki, Cooja, etc.)	Simulated IoT environments: Support real-time data transmission and interactive simulation for IoT platforms.

TABLE 2. Parameter setting.

PARAMETERS	SETTING
learning rate	0.0001 (generator and discriminator)
Generator input noise dimension	100
generator network structure	Multi-layer convolutional and deconvolutional networks
Discriminator network structure	Multi-layer convolutional network
Number of training rounds	1000

Similarity Index (SSIM):

$$IS = exp\left(\mathbb{E}_x\left[D_{KL}\left(p(y|x)||p(y)\right)\right]\right) \quad (2)$$

In Eq. (2), IS evaluates the generated images' diversity and authenticity by calculating the KL divergence between the generated image's conditional class distribution and all images' class distribution. Among them, $p(y|x)$ represents the conditional category distribution generated by the generator given input image x, $p(y)$ is the category distribution over all images, and D_{KL} is the KL divergence.

$$FID = \| \mu_1 - \mu_2 \|_2^2 + Tr(\mathbf{\Sigma}_1 + \mathbf{\Sigma}_2 - 2(\mathbf{\Sigma}_1\mathbf{\Sigma}_2)^{1/2}) \quad (3)$$

In Eq. (3), FID evaluates the difference between the distribution of generated images and real data by calculating the distance between the feature mean and covariance matrix of actual and generated data. Among them, μ_1 and μ_2 refer to the feature means of real and generated data; $\mathbf{\Sigma}_1$ and $\mathbf{\Sigma}_2$ represent their covariance matrices.

$$SSIM(x, y) = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)} \quad (4)$$

In Eq. (4), the SSIM index evaluates the SSIM of x and y by comparing their statistical information such as mean, variance, and covariance. Among them, μ_x and μ_y are the means of input images x and y, σ_x^2 and σ_y^2 are their variances, σ_{xy} is their covariance, and σ_{xy} and C_2 are constants used for stable calculations. The above three indicators comprehensively evaluate the quality of the generated image from different angles. Moreover, the specific derivation and calculation details cover many aspects such as KL divergence, feature mean, covariance matrix, SSIM, etc., ensuring a comprehensive and detailed performance evaluation.

Comparisons were made between the designed system and models such as Deep Convolutional Generative Adversarial Network (DCGAN) [56], Variational Autoencoder (VAE) [57], and the quality of generated images was assessed as shown in Figures 5, 6, and 7:

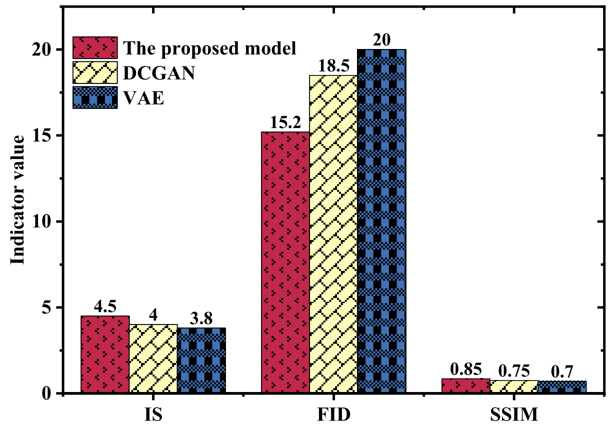

FIGURE 5. Evaluation of image quality generated by different systems.

In Figure 5, the IS of the designed system reaches 4.5, illustrating that the generated images exhibit a high level of quality, demonstrating both good diversity and recognizability. DCGAN has an IS of 4.0, slightly lower than the IoT and GANs integrated systems. In contrast, VAE has the lowest IS at 3.8, suggesting relatively poorer performance in generating high-quality images with a lack of diversity than the other two models. The FID values for the designed system, DCGAN, and VAE are 15.2, 18.5, and 20.0, respectively. The SSIM of the designed system reaches 0.85, indicating a high SSIM between the generated images and real images, preserving most of the structural information. DCGAN has an SSIM of 0.75, which is relatively lower, suggesting a lower SSIM between generated and real images, potentially indicating some structural blurring. VAE's SSIM is the lowest at 0.70, presenting the lowest SSIM between generated and real images, possibly lacking some structural details. These results suggest that the designed system has advantages regarding SSIM and diversity in image generation.

In Figure 6, the proposed system demonstrates superior performance regarding image generation speed, system responsiveness, and user interaction. It exhibits higher efficiency and performance compared to DCGAN and VAE. For instance, the designed system achieves 200 Mbps in data transfer speed, indicating rapid data transmission capabilities. It ensures that students can more smoothly participate in the artistic creation and learning process in a digital environment. DCGAN operates at 150 Mbps, which is comparatively lower and may impact the system's processing speed for large-scale data. VAE operates at 180 Mbps, falling between the IoT and

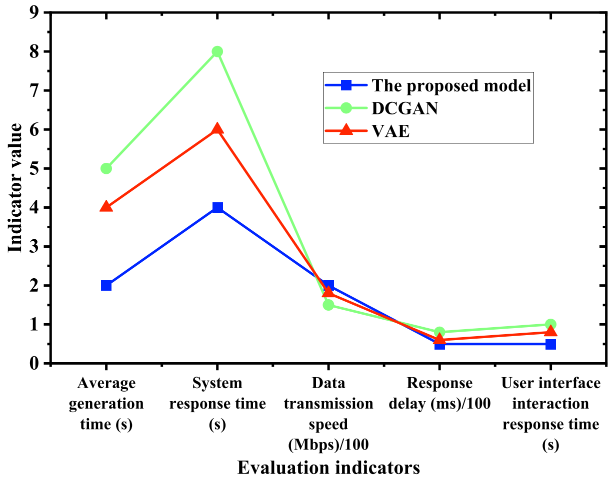

FIGURE 6. Real-time evaluation of different systems.

GANs integrated system and DCGAN, presenting a balanced overall performance.

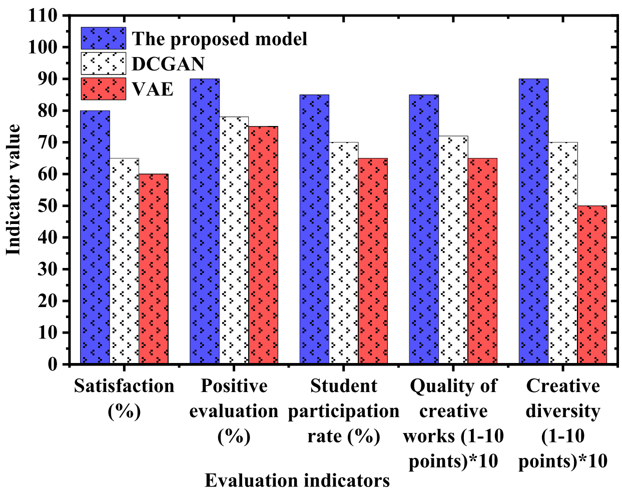

FIGURE 7. Comparative evaluation of student learning outcomes in different systems.

In Figure 7, the IoT and GANs integrated system excels in emotional feedback, learning effectiveness, student participation, quality of creative works, and creative diversity. In terms of satisfaction, it can achieve 80%, while the satisfaction of DCGAN and VAE is 65% and 60%, respectively. This suggests that the proposed model generates higher satisfaction among students, possibly thanks to integrating the advanced technologies of IoT and GANs to provide a more innovative and personalized learning experience. Second, in the proportion of positive comments, the proposed model also performs well, reaching 90%, compared to 78% for DCGAN and 75% for VAE. This indicates that students are more prone to actively evaluate the proposed model, possibly because it better meets their learning needs and creative expectations. Regarding student participation rate, the proposed model also surpasses DCGAN and VAE, reaching 85%, while DCGAN and VAE are 70% and 65%, respectively. This demonstrates that the proposed model has a stronger effect in stimulating student interest and participation, which may be attributed to real-time monitoring and interactivity design. The proposed model has also significantly improved the quality and diversity of creative works. The quality score of creative works reaches 85, and the score for creative diversity is 90. However, DCGAN and VAE perform lower, scoring 72, 70, 65, and 50, respectively. This reflects the proposed model's outstanding performance in promoting students to create high-quality and diverse works. The proposed model is markedly better than DCGAN and VAE in terms of student satisfaction, positive evaluation, student participation rate, quality of creative works, and creative diversity, further proving its excellent performance and innovative value in art education. Overall, the 80% satisfaction and 90% positive evaluation of the design system demonstrate its good performance in promoting learning outcomes. Moreover, learners generally agree that systems are beneficial to their learning. This superiority may be attributed to the real-time monitoring capability of the system, where the real-time monitoring signal still positively impacts the system performance indicators, even in the case of minimal or no interaction among students. Therefore, active student participation and real-time monitoring play an independent and important role in system performance.

In short, the proposed IoT and GANs integrated system has significant advantages regarding real-time performance, image generation, and student learning outcomes. Thanks to the ability of the proposed systems' generators to generate high-quality, realistic art images through adversarial training, its IS reaches 4.5. This reveals that the generated images perform well in both diversity and recognition. Low FID values (15.2) and high SSIM values (0.85) indicate that the generated images have advantages regarding SSIM and diversity. In contrast, DCGAN and VAE perform relatively poorly on these metrics, showing that the image-generated structure may have some blurring and flaws. The IoT and GANs integrated system's data transfer speeds of up to 200 Mbps ensure the system's outstanding performance in real-time. This enables students to participate more fluidly in the artistic creation and learning process in a digital environment. Compared to DCGANS and VAE, the IoT and GANs system performs well in terms of user interaction, ensuring high efficiency and user-friendliness. This may be attributed to its comprehensive consideration of students' interactive needs for the system, which enhances the overall learning experience. The proposed system has achieved remarkable results in student satisfaction and positive evaluations. This may stem from the system's ability to monitor in real-time, helping to provide timely feedback and promote student emotional engagement. Student participation is enhanced as the system monitors students' creative state and interacts with the generator in real-time. This has had a positive impact on stimulating creative thinking and promoting the practical participation of students. As a result, the synergy of these mechanisms has led to superior performance in all aspects of the IoT and

GANs integrated system. High-quality image generation, fast real-time performance, and effective interactive mechanisms to promote student learning outcomes make this system an innovation in art education, providing students with a more creative and personalized learning experience.

E. DISCUSSION

Within the IoT and GANs integrated system, integrating digital technology into art education goes beyond combining IoT technology and GANs. This integration provides students with a more enriching and innovative learning experience, inspiring their creativity and interest in learning. Related research by Granić [58] also pointed out that the comprehensive application of educational technology can effectively enhance student learning outcomes and engagement.

Based on learner emotional feedback analysis and student participation data, the IoT and GANs integrated system outperforms in stimulating student interest and active participation. This aligns with consistent findings in previous research, such as Eli [59], indicating that innovative teaching technologies can promote student emotional involvement and engagement. In contrast, DCGAN and VAE show relatively poorer performance in this regard, possibly requiring further refinement and optimization.

The effectiveness of generative models directly impacts the quality and diversity of student-created works. Thus, the IoT and GANs integrated system, through the incorporation of IoT technology, enhances the quality and diversity of generated images, thereby driving the creation of outstanding student works. This aligns with previous findings by Baidoo-Anu and Ansah [60], demonstrating that advanced generative models remarkably enhance learners' creative performance.

V. CONCLUSION

A. RESEARCH CONTRIBUTION

This study successfully integrates IoT technology with GANs, constructing a digital teaching system tailored for art education. The system injects new digital elements into art education by continuously monitoring students' creative states, providing real-time feedback, and driving the generation of creative works. Simultaneously, the study demonstrates the significant effects of the IoT and GANs integrated system in enhancing learners' emotional involvement, engagement, and learning effectiveness. Students using the system exhibit higher satisfaction, creating art pieces of higher quality and greater diversity. The introduction of advanced generative models and IoT technology provides more digital tools and resources for artistic creation, offering students a broader platform for artistic expression and propelling innovation and development in art education.

B. FUTURE WORKS AND RESEARCH LIMITATIONS

However, the study's sample size is relatively small and does not cover all types of learners. Future research could expand the sample size to enhance the generalizability of the findings. Some technical details in the system still have room for optimization, such as improving the real-time performance of generative models and advancing the in-depth application of IoT technology. Therefore, plans involve delving deeper into interdisciplinary integration and introducing more advanced technologies like deep learning and augmented reality into art education to enhance the overall system performance. Attention will also be given to individual differences among students using digital teaching systems, tailoring the system to meet the diverse needs of learners. Ultimately, long-term field use and effectiveness assessments will provide insights into the system's impact on students' academic performance and creativity over an extended period.

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