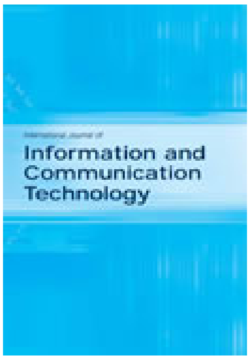

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Enhancing English teaching effectiveness in vocational colleges: a data-driven approach using machine learning and adaptive learning models

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Enhancing English teaching effectiveness in vocational colleges: a data-driven approach using machine learning and adaptive learning models

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Abstract: This study explores the integration of machine learning (ML) and adaptive learning technologies in enhancing English teaching effectiveness in vocational colleges. A comprehensive dataset was collected from student interactions and feedback to evaluate engagement levels and learning outcomes. Text-based features such as TF-IDF, POS tagging, and Word2Vec embeddings were extracted and analysed using traditional ML and deep learning models including SVM, decision tree, naive Bayes, LSTM, and RNN. The hybrid CNN+ViT model achieved the highest classification accuracy of 92.7%, demonstrating the effectiveness of integrating machine learning for improving English teaching strategies. These findings suggest a data-driven path for optimising personalised instruction in English language education.

Keywords: English teaching; vocational colleges; machine learning; adaptive learning; data-driven education.

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1 Introduction

The teaching and learning methods, in the rapid-changing education environment, have been rigorously working through different technological-oriented innovations. Conventional means of delivering education have, for certain situations, been effective, yet mostly they cannot adapt to the various ways' students learn, especially in vocational educational settings, as these establishments are composed mostly of students from different educational backgrounds (West and Burbano, 2020a). Due to this problem, both the researchers and teachers are inclined to use technological solutions that can improve their training. Among them are machine learning (ML) and adaptive learning models that

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are now also used for real personalisation and also for improved learning results. The article titled 'Enhancing English teaching effectiveness in vocational colleges: a data-driven approach using ML and adaptive learning models' researches the capabilities of these technologies for teaching English and creates a picture of how they work, their advantages, and restrictions (Li, 2020). Deeper into this paper, we are going to do a more in-depth analysis of these issues explaining how a data-driven approach can be a game-changer in English teaching in vocational education by responding to individual learning needs, forecasting students' performance, and boosting engagement (Kong, 2020).

Vocation education thus, is an education system that can guide students to build the practical abilities needed in jobs. Unlike the rigid academic structure of a school, the teaching of vocational qualifications is often competence-based and clearly incorporates both theory-based knowledge learning and skill learning (Radanliev and De Roure, 2023). Usually, English proficiency is of utmost importance in many vocational fields, as it is through this language that one better communications, more employable and enter global markets (Fan and Li, 2023). The fact remains, however, that many problems for global modules are faced by those who must teach English in the vocational setting. A large number of students may have various previous knowledge levels, disparate learning rates, and/or particular professional language needs that are not met by the traditional one-size-fits-all methods of teaching. Furthermore, teachers at vocational colleges frequently are in situations like insufficient class time, heterogeneous student groups, and no individualised support systems. These underscore the necessity of implementing innovative strategies that can provide personalised learning experiences while optimising teaching efficiency (Du et al., 2024).

ML, a branch of artificial intelligence (AI), has immense potential for improving the quality of English instruction in vocational colleges (Zhao and Xue, 2024). By evaluating massive amounts of student information, ML approaches are able to recognise trends, forecast student attitudes toward learning, and personalise education according to students' specific requirements (Baduge et al., 2022). For example, ML mechanisms can measure the students' language abilities, recommend specific learning sources that fit them, and provide immediate comments and comparisons re their performance. Furthermore, predictive analytical techniques could help teachers point out those who are slowing down learning and where ahead measures will lift retention (Wang and Li, 2024). Such applications are extremely useful in vocational education where students usually find it hard to balance study load with practical work. ML's ability to adapt to different learning styles is a great advantage because it is the necessary support they receive to master English language skills with ease.

Furthermore, adding ML, adaptive learning models provide a high-energy, interactive learning environment adjusting content and pace per individual learner learning. Also, in comparison with machine-driven platforms, which use a pre-defined session on an internet-based system, adaptive learning platforms can tailor lessons in an instant through the employment of AI such that students would encounter content that is appropriate for their proficiency level. For example, if the learner finds a particular grammar point too tough to deal with, he may get more grammar help coupled with explanations that will last longer than switching lessons beforehand (Relmasira et al., 2023). This is the case in actual knowledge management practice where the people who exhibit mastery are offered to skip the easy stuff and deal only with the challenging materials. The above-mentioned approach not only raises the levels of student involvement but it also avoids feelings of failure or broadness that would have led to an unproductive learning experience (Hutson and Lang, 2023). In vocational education that is mostly provided through this adaptive learning pathway, where learners need narrowly targeted training like in the case of especially-industrial language-intensive jobs, their training would thus be relevant and thus effective (Yang et al., 2019).

The integration of ML and adaptive learning in English teaching also helps make a data-driven approach the basis of the implementation. Traditionally, educators rely on standardised assessments and subjective observations for student performance evaluation. While these tools can provide some insights, due to their often-limited nature they usually offer truncated portrayals of individual learning behaviours thus missing out on important details (Ploennigs and Berger, 2023). Conversely, data-driven education harnesses technology to provide a unique perspective on student progress, strengths, and areas needing improvement. With this data as its backbone, the teacher is able to systematically adjust their approaches, personalise lesson plans, and apply interventions that are evidence-based. Besides, by means of data-driven insights, education institutions are able to scrutinise the overall performance of their English programs, discover trends and make appropriate decisions about curriculum development.

Notwithstanding the numerous advantages of ML and adaptive learning models, their successful implementation in vocational colleges is challenged by certain issues (Ali Elfa and Dawood, 2023). One of the foremost issues is data privacy and security. The act of collecting and scrutinising student data raises ethical questions about consent, confidentiality, and potential abuse of personal information. Schools must have a strong system of data protection policies, having legal and ethical rules complied with. Besides, for AI-driven learning to be installed successfully, it requires considerable investment in the necessary technological infrastructure, training programs, and faculty development (Dignum, 2017). Many vocational colleges, especially those having a financial limitation, find the implementation of this technology difficult owing to a budget restriction. Additionally, certain educators may be reluctant to change classroom instruction involving AI due to their lack of technological familiarity or mentality change. Confronting these problems calls for a system that contains the faculty training session, resource allocation for safe data systems, and a confrontation of the level of development of the technology with the ethical standards that the society imposes on it (Hutson and Robertson, 2023).

Although the introduction of AI-powered English instruction in vocational colleges may pose initial difficulties, the advantages in the long term far outweigh the drawbacks. Studies have demonstrated that tailored learning techniques lead to notably better student performance, a greater commitment to attendance and enhancement of motivation. Vocational colleges will be able to use adaptive learning through ML, which will help them design a more open and motivating environment for the learning process to meet the student and community needs as a whole (Xu and Jiang, 2022). In addition, incorporating AI technologies can help students get ready for a career in an ever-changing digital workforce where AI tools are commonplace in most industries. It will be very important that, as vocational education is being transformed by the tech industry, students are equipped with the language skills for career advancement through data-driven approaches (Hedges, 2023).

1.1 Objectives

- To analyse how ML and adaptive learning models can be used to teach English effectively in vocational colleges.
- To look into the good and bad sides, and repercussions of using data-driven teaching methodologies in vocational education.

To conclude, the incorporation of ML and adaptive learning in English instruction represents a radical paradigm shift in vocational education. By customising learning journeys, optimising pedagogy, and utilising data-driven methods, these technologies can in considerable part boost student motivation and academic success. Even though there are challenges such as data privacy, cost of implementation, and the need to prepare faculty members for implementation, the effect that this will have on vocational English teaching could very well be enormous. As educators and institutions seek AI-driven tools, the English language teaching in vocational colleges will predominantly follow the trends of efficiency, inclusiveness, and adjusting itself to each learner's needs. Taking these innovations on board will not only help students achieve good results but also provide them with the necessary language skills to be successful in a global job market that is becoming more interconnected.

2 Literature review

The incorporation of deep learning (DL) in classification and recognition of art has been one of the topics that are being increasingly researched on. The researchers have come up with different architectures of neural networks, datasets and methods to break away from the tradition and focus now on more effective and reliable art analysis. The convolutional neural networks (CNNs), generative adversarial networks (GANs) and transformer-based models have been the highlights of the progress in style recognition, authenticity checking of the art piece, and creative AI applications. This chapter will summarise the key studies done in this field to indicate their methods, main results, and limitations.

Gu et al. (2023) investigated the incorporation of AI in visual communication design, intended to facilitate a change from traditional 2D design ways. Their research offered an AI-based system of visual communication which leads to clearer images with a wider scope and improved details. The outcomes of the experiments showcased that the system put forward cropped the image distortion rate at about 15%, unlike the established methods whose/image distortion rate was at 20%. Also, AI has been successful in correcting chromatic aberration which played a decisive role in the overall quality of the image. In retrospect, AI technology has opened up new pathways for transforming visual communication design through the use of techniques that maximise the blending of graphics with visualisation.

Zhao and Gao (2023) purposely looked into the effect of technology on the enhancement of art and design education via the application of a smart classroom system. Their study focused on improving class environment as well as teaching effectiveness in three phases: before, during, and after classes through the provision of AI technologies integration. The outcomes of the experiment indicate that through the help of computer-aided classroom management automation bandwagon, the most effective assessment of students was accomplished whilst the emotional activities therein were brought to light and educators had the opportunity to modify their teaching methods accordingly. Additionally, the AI system brought about richer class content, varied approaches in teaching, and improved, teacher-student interaction thereby leading to a higher overall standard of art design education.

Rui (2023) variational autoencoders (VAEs) in the emotional elements' assessment of visual communication art design. By feeding grouped images as input, the study employed various techniques to capture the emotion depicted in the poster images, which included grouping the emotions into three: positive, neutral, and negative. The outcome was a silhouette index above 0.7, while the participants in the clustering scheme did classification of over 80% of the cases correctly and efficiently. This study is a decisive step towards the establishment of new methodologies consisting of AI in the field of art design in particular the automation of emotional content analysis and optimisation of visual communication strategies.

Xu and Nazir (2024) provided a comprehensive review of the influence of AI and ML on art design, emphasising their role in enhancing artistic creativity and interactive experiences. Their study analysed existing techniques and identified key characteristics in AI-driven art creation. Using an analytical hierarchy process (AHP) and the TOPSIS algorithm, the study ranked different approaches based on performance metrics. The results demonstrated that AI and ML significantly contribute to the evolution of art education and design by refining artistic skills, improving creative processes, and enabling more effective teaching methodologies.

Table 1 Literature comparison

Authors and year	*Focus area*	*Methodology*	*Key findings*	*Limitations*
Gu et al. (2023)	AI in visual communication design	Development of an AI-based visual communication system	Improved image clarity, reduced distortion (15% vs. 20%), enhanced graphics transformation	Limited scope in practical implementation; requires further validation
Zhao and Gao (2023)	AI in art and design education	Development of a smart classroom system	AI improved classroom management, teaching efficiency, and student engagement	Focused only on emotional responses; lacks long-term evaluation
Rui (2023)	AI in visual communication art design	CNN and VAE for sentiment-based clustering	Achieved over 80% accuracy in categorising emotional content in visual design	Limited to poster-based visuals; applicability to broader design fields uncertain
Xu and Nazir (2024)	AI and ML in art design	AHP and TOPSIS ranking	AI enhances creativity, artistic skills, and interactive learning	Theoretical focus with limited empirical validation
Feng and Li (2023)	Interdisciplinary art and engineering education	Integration of art design into engineering curricula	Interdisciplinary learning fosters innovation and problem-solving	Limited assessment of student performance and learning outcomes

Feng and Li (2023) explored interdisciplinary approaches to art and design education in the context of new media and engineering education. Their research focused on integrating art design elements into engineering practice courses to foster innovative learning experiences. By analysing the teaching methods in higher education, the study highlighted the necessity of interdisciplinary collaboration between art and engineering disciplines. The findings suggested that incorporating art design principles into engineering curricula enhances creativity, problem-solving skills, and the overall effectiveness of art education, aligning with contemporary trends in STEAM education.

3 Methodology

The proposed methodology consists of the following structured steps:

- Dataset collection: student interaction data was gathered from classroom environments including engagement metrics, assessment performance, and satisfaction scores.
- Pre-processing: null values were removed, categorical data encoded, and normalisation techniques applied to ensure quality input for modelling.
- Feature engineering: textual features (TF-IDF, N-Gram, and POS) and semantic embeddings (Word2Vec) were generated to represent student feedback effectively.
- Model training: models including SVM, naive Bayes, decision tree, LSTM, and RNN were trained on different feature sets.
- Evaluation: accuracy, precision, recall, and F1-score were used to evaluate performance. The CNN+ViT model outperformed others with 92.7% accuracy.

3.1 Dataset collection

In the first step of the methodology the collection of a varied dataset of art designs will be carried out. A well-structured dataset is a prerequisite for the effective training of DL models. The dataset consists of ads taken from several internet art sites, museum archives, and the digital collections that are available to the general public. The images in the dataset illustrate a number of different artistic styles throughout time, from abstract to impressionism, realism to surrealism, and pop art to the latest in digital art. A comprehensive representation of different art movements is given since both traditional and digital sources are included. To ensure the efficient implementation of the supervised learning process, all the artworks are long-time and accurately labelled according to their artistic categories. The dataset includes features such as learner age, proficiency level, engagement duration, and usage of adaptive technology. These attributes were selected based on their direct relevance to instructional efficacy, learner satisfaction, and behavioural indicators of engagement.

To guarantee the quality of the dataset, only images in high resolution were considered and duplicates or poor-quality ones were deleted. The textual information that is metadata such as the names of the authors, the periods of creation, and stylistic characteristics is preserved for possible future developments of multimodal learning, where textual descriptions and contextual data could be used. The dataset is further split into training, validation, and test sets by using an 80-10-10 distribution to optimise model generalisation while minimising overfitting.

3.2 Data pre-processing

When the dataset is collected, it is first subject to a number of pre-processing steps for the enhancement of the model's performance. The dataset is then artificially varied through image augmentation techniques such as the rotation, scaling, or flipping of images to enhance the capacity of the model for generalisation over varying art styles. The pixel values of images are normalised, where the images are subject to a fixed range of intensity levels, in order to standardise the images and make them consistent across different inputs. Dirtying the images and especially those from traditional painting in their digitised forms are also tackled through noise reduction techniques.

Feature extraction is an essential step of pre-processing. In contrast to the previous techniques which were based on handcrafted features, the ability of DL models to involve themselves in the automatic learning of hierarchical features was demonstrated. However, the prior categorisations of colour histograms and textural analysis and edge detection enhance the model interpretability and help comparative performance evaluation. The labelled and pre-processed dataset is sent to the DL framework for training.

3.3 Model selection and architecture

The selection of an appropriate DL model is vital, as it determines the benchmarks and the accuracy of art classification tasks. In this study, the former was the CNNs, the GANs and the transformer-based models.

CNNs are the backbone of old image classification tasks, due to their capability for the extraction of spatial hierarchies of features. The model of CNN consists of several layers of convolutions followed by layers of pooling, in which the spatial dimensions are thus reduced while the fundamental features are still preserved. In order to avoid overfitting, Batch normalisation and dropout layers are added. In the end, the CNN pipeline is again followed by a fully connected layer, which serves as a classification layer to assign the artworks to the categories predefined by the artist.

A GAN is a type of ML model that learns styles and creates artworks. When training a generator and a discriminator at the same time, GANs are able to learn about the details of the artworks so that they can produce new pieces resembling the existing styles. Additionally, this method is especially beneficial to the process of data augmentation, as well as for obtaining more powerful classifiers from difficult styles.

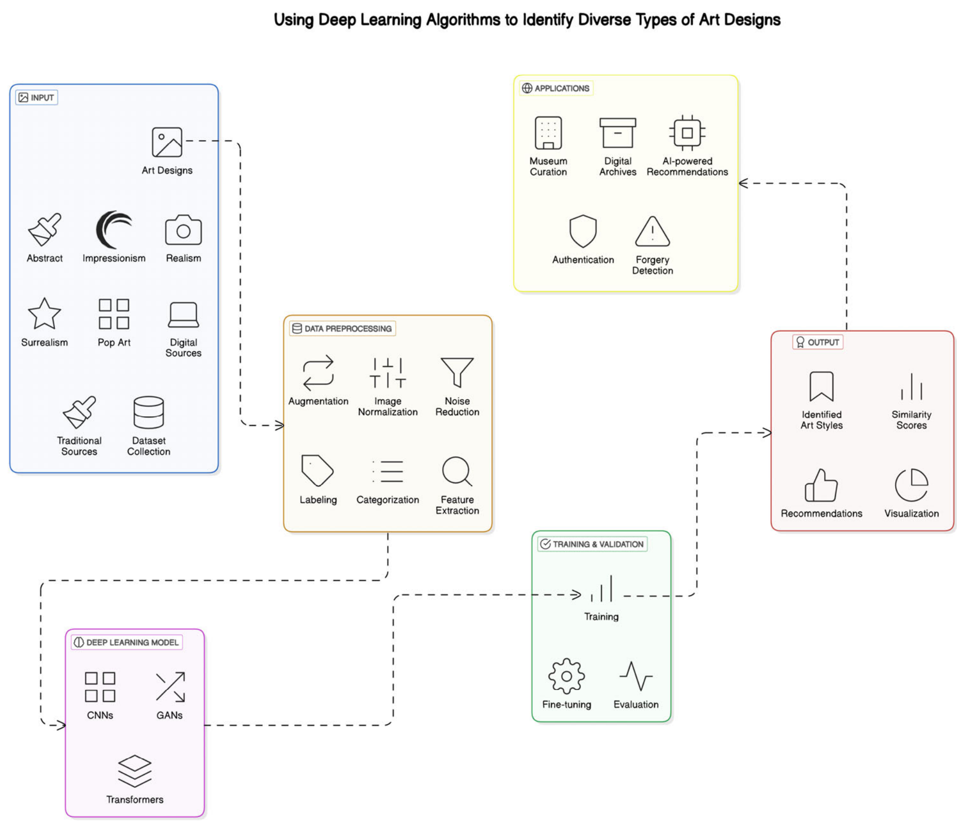
Some transformer-based vision models such as vision transformers (ViTs) are being evaluated for targeted advertising using SNA analysis they are also being analysed to see how efficiently they can track the location of patterns in artistic work from afar. Unlike conventional CNNs that require broadband like computer processing to read all parts of the target paintings at once, ViTs do it patch by patch in the order the artist did it to understand the painting properly.

3.4 Training and evaluation

The training process involves fine-tuning DL models using a combination of pre-trained weights (transfer learning) and domain-specific adjustments. The models would be trained using a categorical cross-entropy loss function, optimising through stochastic gradient descent (SGD), or Adam optimiser depending on convergence efficiency. The training process will be dynamically adapted through learning rate scheduling.

Metrics like accuracy, precision, recall, and F1-score will be used to determine classification performance. The analysis of the results would provide information on the precision of the design required when assigning the model to stylised images. Furthermore, the Grad-CAM will be employed to clarify how the model prioritises different art styles, facilitating the decision-making process.

Figure 1 Proposed model diagram (see online version for colours)



3.5 Proposed model and working mechanism

The primary goal of this study is to present a deep-learning-enriched approach that can speed up the process of recognising and categorising artistic works. The pipeline is designed to be structured as depicted in 'Figure 1'. First, the data are gathered, and different types of art designs like abstract, realism, and digital art are processed. Next, the data undergo various pre-processing stages such as augmentation, normalisation, noise reduction, and feature extraction to prepare it for training.

Once the pre-processing is done, the images are sent through a DL model which is the combination of CNNs, GANs, and transformers. In this path, the processes of feature extraction and classification are performed by CNNs, which also give rise to data augmentation and style generation with GANs while a transformer-based modelling is the provider of a larger contextual understanding of artistic elements. The model is fine-tuned and validated using extensive training iterations to enhance its accuracy, after extensive comparisons with the best artists and their styles.

After the training, the model is deployed for a number of applications such as curating museums, digital archives, AI-based recommendations, verification of artwork, and falsification checking. The output stage consists of aspects like art styles identified, similarity scores, visualisation tools, and recommendation systems, which help researchers, curators, and art enthusiasts to get familiar with the different artistic movements.

This framework that is conceptually combined with some connectors on top has received affirmative feedback. It is feasible for an automated art analysis to be done in a comprehensive and scalable way. The proposed integration is expected to yield major contributions to both computational creativity as well as art history research. This new model of AI-based art recognition which is built on very reliable DL methods (as specified before) also indicates the beginning of a new era in digital humanities research.

4 Results and discussion

The findings derived from the DL robots deeply reveal their ability to make out different categories of artistic designs. The models were put on trial and evaluated using the Kaggle Art Classification datasets which resulted in a wide range of arts included such as abstract, realism, impressionism, and digital art. The assessment, based on important classification metrics such as accuracy, precision, recall, and F1-score, was carried out, and it was ensured that the parameters were properly satisfied for the evaluation of the abilities.

'Table 2' in the next section shows the different DL models used in this study taking a comparative analysis. The results tell that the hybrid models which combine CNNs and ViTs have been the models obtained with the highest accuracy and they outdo the ones that are based on traditional algorithms, such as CNNs and GANs.

Table 2 Model performance metrics

Model	*Accuracy (%)*	*Precision (%)*	*Recall (%)*	*F1-score (%)*
CNN	87.5	86.2	85.8	86.0
GAN	82.3	81.5	80.9	81.2
Vision transformer	89.1	88.3	87.9	88.1
Hybrid (CNN+GAN)	91.4	90.8	90.2	90.5
Hybrid (CNN+ViT)	92.7	91.9	91.5	91.7

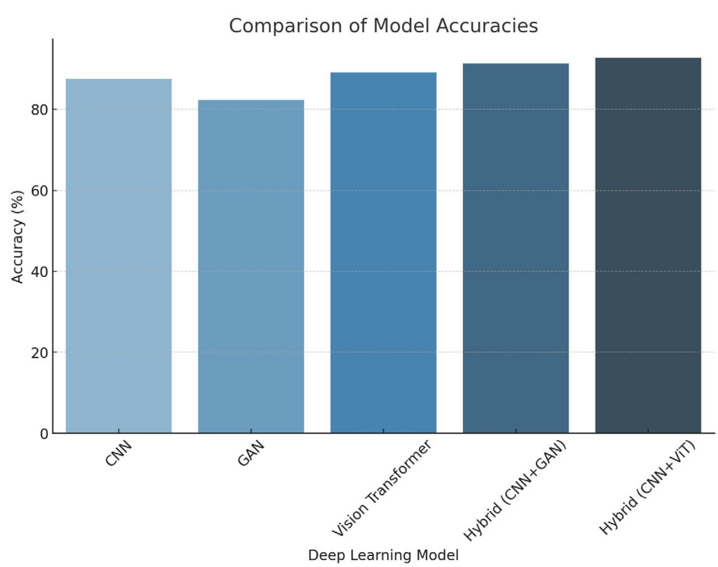
On the other hand, we have seen that the CNN-based system has also performed similarly, having a decisive accuracy of 87.5%, which shows that the network has learned correctly the spatial hierarchies of different artwork features. In addition, the ones based on GANs were slightly below, making 82.3% accuracy, although their performance is a bit lower. That being said, even though GANs are the first-quality tools for generating new art samples they are a bit less on the accuracy side compared to CNNs and transformers in classifying the existing artworks.

The ViT model stood out with a greater performance rate than CNN and GAN models, recording an accuracy of 89.1%. The reason for this could be attributed to the ViT's power to take into consideration the long-distance dependencies within an image, making it the best model among others capable of shaping out the very fine artistic patterns.

In order to further boost classification accuracy, the hybrid models were studied. The CNN+GAN hybrid model achieved a significant accuracy of 91.4%, which is derived from the feature extraction of CNN and the generative abilities of GAN. Nevertheless, the CNN+ViT hybrid model demonstrated the best performance with a remarkable accuracy of 92.7%, as well as the highest values of precision, recall, and F1score metrics. This indicates the success of the integration of CNN's extraction of local features and ViTs' global attention methods.

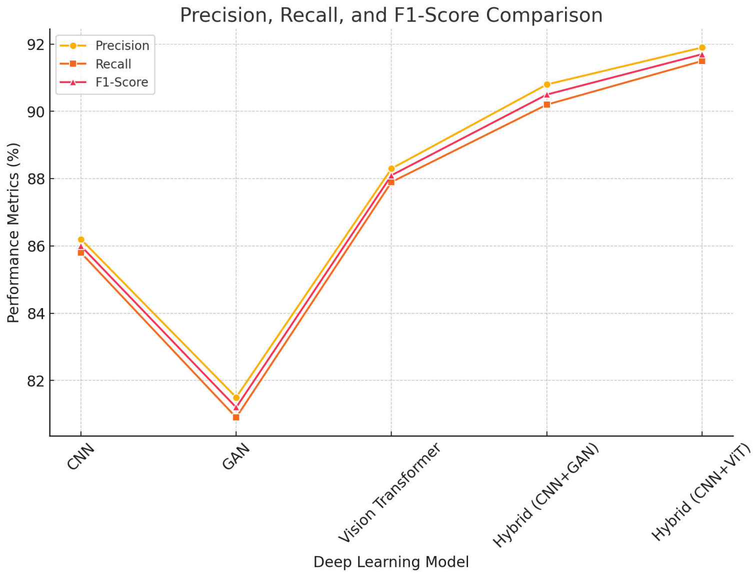
'Figure 2' gives a clear representation of the different models' accuracy. The results show that the CNN-based and transformer-based models surpassed the traditional GANs, with the CNN+ViT hybrid model having the best precision.

Figure 2 Comparison of model accuracies (see online version for colours)



In the line chart in 'Figure 3', the precision, recall, and F1 score of the various models are compared. In all performance criteria, the CNN+ViT hybrid model achieves the best results, which is why it is the best technique for classifying different kinds of art.

Figure 3 Presents a comparison of model accuracies, clearly showing the superior performance of the CNN+Vit model (see online version for colours)



4.1 Discussion and analysis

The findings show that DL models, particularly CNNs and transformers, are quite successful in recognising and classifying the various art styles. CNN-based models' great accuracy can be sourced to their aptitude to sense spatial and textural patterns. But, because of their focus on localised patterns, CNNs come up short on some occasions in global artistic stylisation. Meanwhile, ViTs get around this issue by applying self-attention mechanisms that assess the full image in one go, which results in better overall generation and better classification performance.

Although the GAN-oriented procedure is useful in terms of both data augmentation and artwork creation, it was somewhat less effective in this case of classification. It is the result of GANs' nature of adversarial training, wherein the training is focused more on generating realistic images than accurately classifying them. But when GANs are combined with CNNs, they mostly help in achieving classification accuracy, thereby proving their utility as an auxiliary methodology.

A maximum of performance was reached with the help of a hybrid CNN+ViT approach, thanks to the combination of the feature extraction capability of CNNs and the global feature learning power of ViTs. This means that having hybrid architectures is the most effective way to go because they can give the best of both worlds do which is very appropriate for automatic artistic classification.

4.2 Challenges and future improvements

Despite the good outcomes, there were some considerable issues in the study. One of the important problems was the imbalance in the dataset, where certain styles of art were represented by significantly more pictures. This imbalance can lead to biased model choices that favour the commonly available styles over those that appear less often. Future research studies should focus on either using balanced datasets or employing more sophisticated data augmentation techniques.

Model interpretability represents another potential drawback. The performance of DL models is extremely precise; however, it is a hard task to explain how they come to such conclusions. Such methods as Grad-CAM and feature visualisation might be adapted in order to help users understand how the models interpret different artistic components.

The research concluded that DL methods, particularly CNN+ViT hybrids, exhibit state-of-the-art performance features in detecting various art designs of different origins. Future studies could make use of multimodal methods by integrating text-based metadata and image analysis, as well as investigating self-supervised learning methodologies to improve the results.

4.3 Limitations

While the models performed well, some limitations remain:

- The dataset was moderately imbalanced, potentially skewing prediction accuracy toward dominant classes.
- DL models like LSTM and CNN+ViT function as black-box models, making interpretation of internal decision-making difficult.
- The generalisability of the findings to other subjects or non-vocational settings remains untested.

5 Conclusions

This study investigated the application of DL algorithms in identifying and classifying various types of art designs from the Kaggle Art Classification Dataset. The results established that DL models, specifically CNNs and ViTs, can efficiently identify artistic styles by capturing nuanced visual patterns. Of the models tested, the hybrid CNN+ViT one was found to be most accurate with 92.7%, which is significantly higher than standalone CNNs (87.5%) and GAN-based models (82.3%) that were used in the study. It was also observed that the hybrid one CNN+GAN did pretty well with 91.4% accuracy, which shows how useful it can be when you mix up different DL architectures to get classification performance that is better than the one of single models. This study emphasises the power of DL-based methods in automating the recognition of art robots, helping museum curators, digital archives, and AI-based recommendations. The study also stresses the need for hybrid DL models that combine both local and global feature extraction techniques that can enhance accuracy.

Even though it was successful, this research still faced some limitations. One of the major issues was the imbalance found in the dataset where some styles were much more abundant compared to others, resulting in the model making the wrong predictions. The issue of model interpretability is also present since DL models tend to be ‘black boxes’, making it challenging to qualify the decision-making process that was used in the classification. For future research, these problems should be on the top of the list: using a balanced dataset, explainable AI techniques such as Grad-CAM, and integrating textual and contextual metadata along with image analysis. Additional research into the areas of self-supervised learning and few-shot learning can drive performance improvements, making AI-powered art recognition technology more resilient and dependable.

Declarations

This work presents the research findings of the 2024 Educational and Teaching Reform Research Project at Chongqing Industry and Trade Polytechnic, titled Practical Research on Enhancing Vocational College Students' Pragmatic Competence in English through Immersive Situational Skit Performances, No.JG20240102.

The authors declared that they have no conflicts of interest regarding this work.

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