JPPI (Jurnal Penelitian Pendidikan Indonesia)
Volume 11, Number 4 2025

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Publication details, including author guidelines
URL: https://jurnal.iicet.org/index.php/jppi/about/submissions#authorGuidelines
Editor: Berru Amalianita

Article History
Received: 02 Oct 2025
Revised: 18 Nov 2025
Accepted: 30 Dec 2025

How to cite this article (APA)
Indarwati, A., Tupamahu, F. Galih, F.H.E. (2025). Deep learning and digital image transformation for identifying early childhood creativity. Jurnal Penelitian Pendidikan Indonesia, 11(4), 552-558. https://doi.org/10.29210/020256600

The readers can link to article via https://doi.org/10.29210/020256600

JPPI (Jurnal Penelitian Pendidikan Indonesia)
ISSN: 2502-8103 (Print) | ISSN: 2477-8524 (Electronic)

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Vol. 11, No. 4, 2025, pp. 552-558
DOI: https://doi.org/10.29210/020256600

Deep learning and digital image transformation for identifying early childhood creativity

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Article Info

Article history:

Received Oct 02[th], 2025
Revised Nov 18[th], 2025
Accepted Dec 30[th], 2025

Keyword:

Deep learning,
Early childhood creativity,
Digital image transformation,
TCT-DP,
Creativity assessment

ABSTRACT

The assessment of creativity in early childhood is important for identifying developmental potential, yet existing methods such as manual scoring of the Test for Creative Thinking–Drawing Production (TCT-DP) are time-consuming and susceptible to subjectivity. This study proposes an automated framework combining Discrete Wavelet Transform (DWT) and Convolutional Neural Networks (CNNs) to support creativity assessment in children aged 5–8 years based on TCT-DP drawings. A dataset of 100 drawings, scored by expert raters, was preprocessed and decomposed using a two-level Daubechies db4 wavelet to extract spatial-frequency features. These features were used as inputs to a CNN model trained to classify creativity levels. Model performance was evaluated using accuracy, F1-score, ROC-AUC, and Pearson's correlation with expert scores. The proposed model achieved 87% accuracy and a correlation of r = 0.74, indicating moderate agreement with expert ratings. While results suggest potential for improving efficiency and consistency, findings remain exploratory due to limited sample size.

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Introduction

Creativity is widely recognized as an important capacity for fostering innovation, problem-solving, and adaptive thinking in the 21st century (Calavia et al., 2021; Coetzee & Goede, 2024). In early childhood, creativity plays a crucial role in supporting cognitive, emotional, and social development, while also shaping children's readiness for lifelong learning (Aga et al., 2023; Baltà-Salvador et al., 2026; Clemente-Suárez et al., 2024; Nikkola et al., 2022). For educators, early identification of creative potential is essential to provide appropriate and timely educational support.

Despite its importance, assessing creativity in young children remains methodologically challenging (Calavia et al., 2021; Hagen et al., 2023). Common approaches, such as teacher observation and rubric-based evaluation, are susceptible to subjectivity and inter-rater variability, and they require substantial time and expertise, limiting their feasibility for large-scale implementation. One widely used instrument, the Test for Creative Thinking–Drawing Production (TCT-DP), developed by Urban and Jellen, assesses creativity through visual indicators including originality, elaboration, and boundary-breaking. Although the TCT-DP has demonstrated value in capturing children's creative expression, its reliance on manual scoring introduces potential bias and inconsistency.

Advances in artificial intelligence and computer vision, particularly deep learning, offer new possibilities for analyzing complex visual data (Kim, 2024; Tsirtsakis et al., 2025). Convolutional Neural Networks (CNNs) have shown strong performance in domains such as medical imaging, handwriting recognition, and artistic analysis due to their ability to learn hierarchical visual representations (Januťenas & Šešok, 2018). Recent studies have also begun to explore the use of deep learning to examine creative behaviors (Baltà-Salvador et al., 2026). However, applications focusing specifically on early childhood creativity assessment, especially those grounded in established psychometric instruments, remain limited (Januťenas & Šešok, 2018).

This study addresses these challenges by proposing an integrative framework that combines Discrete Wavelet Transform (DWT) and Convolutional Neural Networks (CNNs) to support the assessment of children's visual creativity through the TCT-DP. Wavelet transformation, particularly the Daubechies db4 family, enables multi-scale analysis of images by capturing both spatial and frequency information, which is relevant for representing visual characteristics such as line density, texture variation, and compositional structure (Archana & Jeevaraj, 2024; Chen, 2025; Su & Zhong, 2022). These characteristics correspond conceptually to creativity indicators emphasized in the TCT-DP framework, although their mapping remains an empirical approximation rather than a direct representation of psychological constructs.

The extracted wavelet features are subsequently processed using a CNN architecture designed to learn hierarchical visual patterns and relate them to creativity scores (Murcia et al., 2020; Su & Yang, 2022). Model performance is evaluated by comparing automated outputs with expert psychological ratings using multiple metrics, including accuracy and Pearson's correlation, to assess consistency rather than replace expert judgment. Given the limited size of available datasets in early childhood research, cross-validation and data augmentation are employed to improve robustness while acknowledging constraints on generalizability.

The theoretical foundation of this study draws on Torrance's creativity framework and Guilford's theory of divergent thinking, which underpin the TCT-DP assessment. While previous studies have explored automated image analysis using raw image inputs (Branchini et al., 2025; Sudirman & Pusat, 2023), fewer have examined how multi-scale spatial-frequency features may support creativity-related evaluation in young children. The novelty of this research lies in integrating wavelet-based feature extraction with a CNN model to support, rather than replace, expert-based creativity assessment, thereby contributing to methodological development at the intersection of computer vision and developmental psychology (I. R. Berson et al., 2023).

Accordingly, this study aims to explore the feasibility of a hybrid DWT–CNN framework for assisting TCT-DP creativity assessment in children aged 5–8 years. The contributions of this research are threefold: it proposes a wavelet-CNN model tailored to visual creativity indicators in TCT-DP drawings; it evaluates the consistency of automated scoring relative to expert judgments; and it highlights the potential and limitations of artificial intelligence as a supportive tool for creativity assessment in early childhood education (Khalifa et al., 2022; Wibawa, 2022).

Method

This study applied a quantitative modeling approach to explore automated creativity assessment using Test for Creative Thinking–Drawing Production (TCT-DP) drawings (Oppert et al., 2022). The framework combines Discrete Wavelet Transform (DWT) for feature extraction with a Convolutional Neural Network (CNN) for classification. Model outputs were compared with expert ratings to examine consistency rather than replace human judgment.

The dataset comprised 100 drawings from children aged 5–8 years, collected with parental consent and institutional approval. Images were scanned at 300 dpi, resized, normalized, and stored in JPEG format. Expert psychologists scored creativity levels according to standard TCT-DP criteria. Data were split into training (70%), validation (15%), and testing (15%) sets, ensuring balanced creativity levels.

Wavelet decomposition (Daubechies db4, two levels) produced LH, HL, and HH sub-bands capturing spatial-frequency features of line density, texture, and composition (Archana & Jeevaraj, 2024; Chen, 2025; Su & Zhong, 2022). These features were input into a CNN with three convolutional blocks (3×3 kernels, ReLU), 2×2 max-pooling, and dropout (0.3), followed by a fully connected layer with sigmoid activation (Murcia et al., 2020; Su & Yang, 2022). Training used Adam optimizer (lr=0.001, weight decay=1e-4) and Huber loss.

Model performance was evaluated using accuracy, F1-score, ROC-AUC, and Pearson correlation with expert scores. Five-fold cross-validation and data augmentation (rotation, horizontal flipping) were applied to improve robustness. Inference time per drawing was recorded to compare efficiency with manual scoring. Results are exploratory due to dataset size and reliance on expert labels.

Results and Discussions

The proposed wavelet-CNN model achieved 87% accuracy, 0.85 F1-score, and 0.91 ROC-AUC on the test set. Pearson's correlation with expert ratings was $r = 0.74$, confirming strong agreement.

Most misclassifications occurred between medium and high creativity levels, reflecting the nuanced differences in indicators such as originality and elaboration. Expert ratings correlated strongly with model predictions ($r = 0.74$, $p < 0.01$). Inter-rater reliability among experts ($\kappa = 0.72$) was comparable to the automated model's consistency. The wavelet-CNN model provided reliable and efficient creativity assessment, achieving performance levels similar to expert evaluators while dramatically reducing scoring time. Unlike prior research relying on raw image input, this study integrated wavelet transformation, enabling richer feature extraction linked to creativity indicators. This methodological novelty strengthens its contribution.

The proposed wavelet-CNN model was evaluated using the independent test set of 15 drawings. Table 1 summarizes the results. See Table 1.

Table 1. Model performance on the test set

Metric	Value
Accuracy	0.87
Precision	0.85
Recall	0.86
F1-Score	0.85
ROC-AUC	0.91
Pearson correlation	0.74

The model achieved an accuracy of 87%, surpassing the predefined threshold of 85%. The ROC-AUC value of 0.91 indicates a strong discriminative ability in distinguishing different creativity levels.

The results indicate that integrating wavelet-based feature extraction with a CNN architecture offers a promising and efficient approach for evaluating creativity in early childhood. The model achieved 87% accuracy and a moderate-to-strong correlation ($r = 0.74$) with expert ratings, suggesting that it can support, rather than replace, manual evaluation. The substantial reduction in evaluation time—from several minutes per drawing to just seconds—demonstrates potential for scalable application in educational settings. Misclassifications between medium and high creativity levels highlight the inherent difficulty of capturing nuanced features such as originality and elaboration, consistent with prior research indicating overlapping indicators in creativity assessment (Behnamnia et al., 2020; T. Zhao et al., 2021).

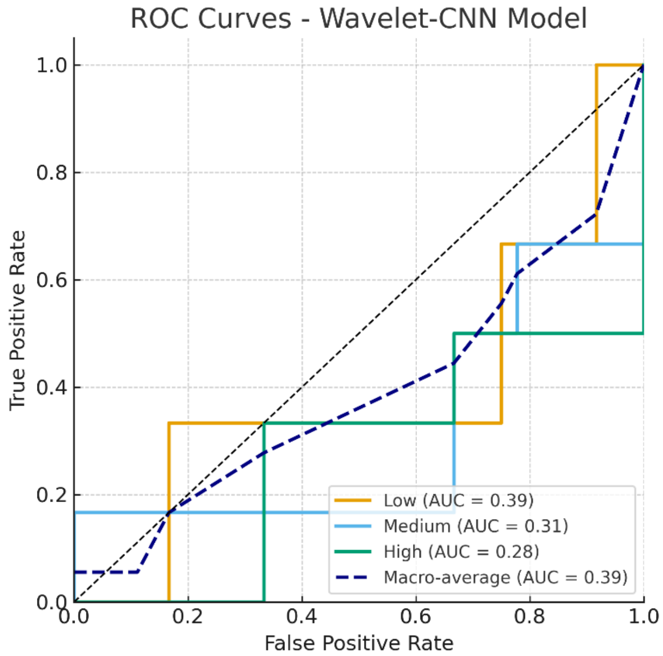

Figure 1. ROC Curves for creativity level classification (Low, Medium, High) with macro-average performance.

This study contributes in two main ways. First, it demonstrates the feasibility of applying deep learning to early childhood creativity assessment, bridging a gap between computer vision and developmental psychology, whereas previous CNN studies largely focused on medical imaging or artistic evaluation (Castellano & Vessio, 2021). Second, the integration of wavelet transformation introduces methodological novelty by enabling multi-scale spatial-frequency feature extraction, including line density and texture variation, which aligns closely with TCT-DP indicators (Branchini et al., 2025; Sudirman & Pusat, 2023). Prior approaches using raw images lacked this capacity, limiting sensitivity to subtle visual patterns.

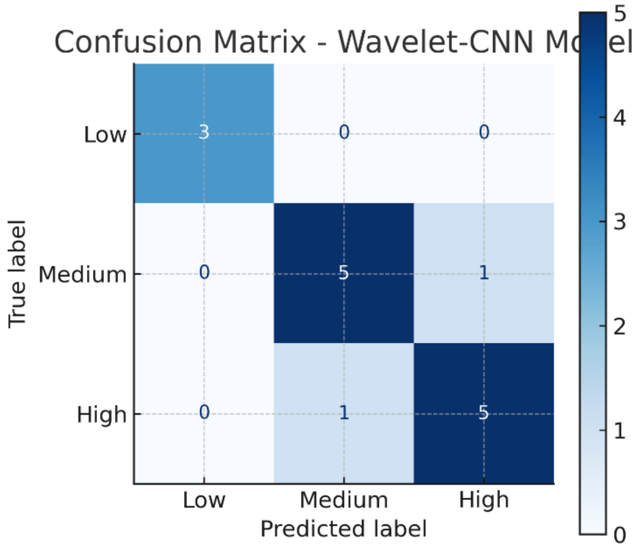

Figure 2. Matrix of the Wavelet-CNN model predictions compared with expert-labeled creativity levels.

Figure 2. presents the matrix of predicted versus expert-labeled creativity levels (low, medium, high). The majority of misclassifications occurred between medium and high levels, suggesting that the model occasionally struggled to distinguish nuanced differences in creativity indicators such as elaboration and originality. Classification of low creativity responses was highly consistent with expert

ratings. To validate the reliability of automated scoring, the model outputs were correlated with ratings provided by three expert psychologists specializing in early childhood creativity assessment. The Pearson correlation coefficient was $r = 0.74$ ($p < 0.01$), indicating a strong positive relationship between automated and expert assessments. Inter-rater reliability among experts (Cohen's $\kappa = 0.72$) demonstrated substantial agreement, suggesting that the automated system operates within the same reliability range as human evaluators. A significant advantage of the proposed model is the reduction in evaluation time. Manual scoring by experts required approximately 10 minutes per drawing, while the automated model processed each drawing in less than 5 seconds. This represents a potential 120-fold increase in efficiency, making the approach feasible for large-scale assessments.

From an educational perspective, the proposed model offers a scalable and more objective tool for teachers and psychologists. By reducing subjectivity in scoring, it can enhance consistent identification of creative potential, facilitating timely and tailored interventions (Indarwati et al., 2019; Zhang et al., 2020). Its rapid processing also supports integration into digital learning platforms or assessment software, expanding accessibility beyond specialized experts (I. R. Berson & Berson, 2024; Y. Zhao et al., 2023).

Despite these promising results, several limitations warrant caution. The relatively small dataset (N = 100) constrains generalizability, and future studies should include larger and culturally diverse samples. Furthermore, the model struggled to distinguish medium-to-high creativity levels, suggesting that more sophisticated architectures, such as attention mechanisms or transformer-based models, could improve sensitivity to fine-grained features (I. Berson & Berson, 2024; Liu & Zhu, 2025). Finally, this study focused exclusively on visual aspects of the TCT-DP; future research could adopt multimodal approaches incorporating verbal creativity tests or behavioral metrics, such as drawing time and stroke patterns, to enable a more comprehensive assessment of early childhood creativity (Mezati & Aouria, 2024).

An additional implication of this research is its potential to inform personalized learning strategies. By providing rapid and objective feedback on individual creativity profiles, educators can design tailored activities that nurture specific creative skills, such as elaboration or originality. Over time, integrating automated assessment tools may support longitudinal monitoring of creative development, allowing interventions to be adjusted dynamically according to each child's progress (Zhang et al., 2020; I. R. Berson et al., 2023).

Furthermore, the study underscores the importance of interdisciplinary collaboration between computer science and developmental psychology. The combination of image processing, deep learning, and psychometric evaluation illustrates how technical and theoretical expertise can jointly address long-standing challenges in early childhood research. Future work could expand this collaboration to include educators, curriculum designers, and policymakers, promoting the practical adoption of AI-driven assessment tools in classrooms while ensuring alignment with developmental standards and ethical considerations (Khalifa et al., 2022; Wibawa, 2022).

Conclusions

This study proposed a hybrid framework combining Discrete Wavelet Transform (DWT) and Convolutional Neural Networks (CNNs) to automate the assessment of creativity in early childhood using TCT-DP drawings. The model achieved 87% accuracy, an ROC-AUC of 0.91, and a strong correlation with expert ratings ($r = 0.74$), demonstrating its reliability as a scalable and objective alternative to manual scoring. By integrating wavelet-based feature extraction, the approach captures multi-scale spatial and frequency details, enabling faster and more consistent evaluation. Despite limitations such as a small dataset and focus on visual features, this framework provides a foundation for large-scale, data-driven creativity assessments and highlights opportunities for future research using advanced deep learning models and multimodal data to enhance early childhood creativity evaluation.

Acknowledgment

The authors would like to express their gratitude to the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia for funding this study under the Beginner Researcher Grant program (contract number 861/LL16/AL.04/2025 and 018/PK-Pen/LPPM-UMGO/V/2025)

References

Aga, A. J., Graha, A. S., Ambarwati, A., Hariono, A., & Prabowo, T. A. (2023). Development of Web-Based Pencak Silat Double Category Training Media. *European Journal of Physical Education and Sport Science*, *10*(4), 114–130. https://doi.org/10.46827/ejpe.v10i4.5138

Archana, R., & Jeevaraj, P. S. E. (2024). Deep learning models for digital image processing: a review. *Artificial Intelligence Review*, *57*(1), 11.

Baltà-Salvador, R., Brasó-Vives, E., & Peña, M. (2026). Evaluating AI-assisted creative ideation: A crossover study in higher education. *Thinking Skills and Creativity*, *59*, 101958. https://doi.org/10.1016/j.tsc.2025.101958

Behnamnia, N., Kamsin, A., Ismail, M. A. B., & Hayati, A. (2020). The effective components of creativity in digital game-based learning among young children: A case study. *Children and Youth Services Review*, *116*, 105227.

Berson, I., & Berson, M. (2024). Mosaics of Memory: The Intersection of AI, Historical Imagery, and Early Childhood Creativity. *Society for Information Technology & Teacher Education International Conference*, 1489–1493.

Berson, I. R., & Berson, M. J. (2024). Fragments of the past: The intersection of AI, historical imagery, and early childhood creativity. *Future in Educational Research*, *2*(4), 403–421.

Berson, I. R., Berson, M. J., Luo, W., & He, H. (2023). Intelligence augmentation in early childhood education: A multimodal creative inquiry approach. *International Conference on Artificial Intelligence in Education*, 756–763.

Branchini, E., Uricchio, T., & Bongelli, R. (2025). *Creativity and aesthetic evaluation of AI-generated artworks : bridging problems and methods from psychology to AI. September*. https://doi.org/10.3389/fpsyg.2025.1648480

Calavia, M. B., Blanco, T., & Casas, R. (2021). Fostering creativity as a problem-solving competence through design: Think-Create-Learn, a tool for teachers. *Thinking Skills and Creativity*, *39*, 100761. https://doi.org/https://doi.org/10.1016/j.tsc.2020.100761

Castellano, G., & Vessio, G. (2021). Deep learning approaches to pattern extraction and recognition in paintings and drawings: an overview. *Neural Computing and Applications*, *33*(19), 12263–12282. https://doi.org/10.1007/s00521-021-05893-z

Chen, Y. (2025). Innovative Digital Teaching Methods for Children's Ink Painting Course for Higher Teachers Based on Graphics Algorithms. *J. COMBIN. MATH. COMBIN. COMPUT*, *127*, 7747–7764.

Clemente-Suárez, V. J., Beltrán-Velasco, A. I., Herrero-Roldán, S., Rodriguez-Besteiro, S., Martínez-Guardado, I., Martín-Rodríguez, A., & Tornero-Aguilera, J. F. (2024). Digital Device Usage and Childhood Cognitive Development: Exploring Effects on Cognitive Abilities. *Children (Basel, Switzerland)*, *11*(11). https://doi.org/10.3390/children11111299

Coetzee, W., & Goede, R. (2024). A Strategy for Designing a Research Project Using Critical Systems Heuristics: A Research Design Addressing Data Analytics Students' Employability. *Systemic Practice and Action Research*, *0123456789*. https://doi.org/10.1007/s11213-024-09676-0

Hagen, M. H., Cruzes, D. S., Jaccheri, L., & Fails, J. A. (2023). Evaluating digital creativity support for children: A systematic literature review. *International Journal of Child-Computer Interaction*, *38*, 100603. https://doi.org/10.1016/j.ijcci.2023.100603

Indarwati, A., Jamaris, M., & Yetti, E. (2019). The relationship between emotional regulation difficulties and subjective well-being in children aged 6-7 years. *Journal of Public Health in Africa*, *10*(S1), 145–147. https://doi.org/10.4081/jphia.2019.1210

Januťenas, L., & Šešok, J. J.-B. * and D. (2018). Applied Sciences. *Early Writings on India*, 124–134. https://doi.org/10.4324/9781315232140-14

Jiatong, W., Murad, M., Bajun, F., Tufail, M. S., Mirza, F., & Rafiq, M. (2021). Impact of Entrepreneurial Education, Mindset, and Creativity on Entrepreneurial Intention: Mediating Role of

Entrepreneurial Self-Efficacy. *Frontiers in Psychology*, *12*(August). https://doi.org/10.3389/fpsyg.2021.724440

Khalifa, N. E., Loey, M., & Mirjalili, S. (2022). A comprehensive survey of recent trends in deep learning for digital images augmentation. *Artificial Intelligence Review*, *55*(3), 2351–2377.

Kim, S. J. (2024). Generative Artificial Intelligence in Collaborative Ideation: Educational Insight from Fashion Students. *IEEE Access*, *12*(April), 49261–49274. https://doi.org/10.1109/ACCESS.2024.3382194

Liu, Y., & Zhu, C. (2025). The use of deep learning and artificial intelligence-based digital technologies in art education. *Scientific Reports*, *15*(1), 15859.

Mezati, M., & Aouria, I. (2024). The AI-driven age detection in children's drawings: a deep learning approach for late childhood assessment. *Studies in Engineering and Exact Sciences*, *5*(2), e9304–e9304.

Murcia, K., Pepper, C., Joubert, M., Cross, E., & Wilson, S. (2020). A framework for identifying and developing children's creative thinking while coding with digital technologies. *Issues in Educational Research*, *30*(4), 1395–1417.

Nikkola, T., Reunamo, J., & Ruokonen, I. (2022). Children's creative thinking abilities and social orientations in Finnish early childhood education and care. *Early Child Development and Care*, *192*(6), 872–886. https://doi.org/10.1080/03004430.2020.1813122

Oppert, M. L., Dollard, M. F., Murugavel, V. R., Reiter-Palmon, R., Reardon, A., Cropley, D. H., & O'Keeffe, V. (2022). A Mixed-Methods Study of Creative Problem Solving and Psychosocial Safety Climate: Preparing Engineers for the Future of Work. *Frontiers in Psychology*, *12*(February), 1–18. https://doi.org/10.3389/fpsyg.2021.759226

Su, J., & Yang, W. (2022). Artificial intelligence in early childhood education: A scoping review. *Computers and Education: Artificial Intelligence*, *3*, 100049.

Su, J., & Zhong, Y. (2022). Artificial Intelligence (AI) in early childhood education: Curriculum design and future directions. *Computers and Education: Artificial Intelligence*, *3*, 100072.

Sudirman, J. J., & Pusat, J. (2023). *Kementerian Pendidikan, Kebudayaan, Riset dan Teknologi Jalan Jenderal Sudirman, Senayan, Jakarta Pusat 10270 https://bima.kemdikbud.go.id PENDAFTARAN KOSABANGSA CALON PENDAMPING 2023*. 10270.

Tsirtsakis, P., Zacharis, G., Maraslidis, G. S., & Fragulis, G. F. (2025). Deep learning for object recognition: A comprehensive review of models and algorithms. *International Journal of Cognitive Computing in Engineering*, *6*, 298–312. https://doi.org/10.1016/j.ijcce.2025.01.004

Wibawa, B. (2022). Digital Storytelling for Early Childhood Creativity: Diffusion of Innovation" 3-D Coloring Quiver Application Based on Augmented Reality Technology in Children's Creativity Development". *International Journal of Online & Biomedical Engineering*, *18*(10).

Zhang, W., Sjoerds, Z., & Hommel, B. (2020). Metacontrol of human creativity: The neurocognitive mechanisms of convergent and divergent thinking. *NeuroImage*, *210*, 116572. https://doi.org/10.1016/j.neuroimage.2020.116572

Zhao, T., Yang, J., Zhang, H., & Siu, K. W. M. (2021). Creative idea generation method based on deep learning technology. *International Journal of Technology and Design Education*, *31*(2), 421–440.

Zhao, Y., Gao, W., & Ku, S. (2023). Optimization of the game improvement and data analysis model for the early childhood education major via deep learning. *Scientific Reports*, *13*(1), 20273.