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Augmented Reality Application for Makeup Style Transfer: A Bibliometric Study

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ABSTRACT

This study examines the development and trends in the use of Augmented Reality (AR) technology applied to makeup style transfer through a bibliometric approach. Using publication data from the Scopus database covering the period from 2013 to 2025, a bibliometric analysis was conducted to map the growth of scientific literature in this field. The results reveal a significant increase in the number of publications, particularly in recent years, indicating a growing research interest. Key contributing authors, journals, and countries were successfully identified, with notable cross-institutional and cross-regional collaborations. The findings also highlight that deep learning methods—especially Generative Adversarial Networks (GANs)—have emerged as the dominant technology in makeup style transfer research, driving progress in the development of realistic and efficient virtual makeup applications. This study underscores the potential of AR as a major innovation in beauty education and practice, offering interactive and personalized learning experiences. Future research is recommended to focus on the development of more accurate and accessible AR technologies to support the ongoing advancement of the beauty industry.

Introduction

In the era of the Fourth Industrial Revolution, Augmented Reality (AR) has made a significant contribution across various sectors including science, industry, and education by adding a new dimension to everyday life. According to Britannica (2023), as cited by Živičnjak (2024), AR is defined as the process of merging or enhancing video or image representations with computer-generated data for practical use. Cheng et al. (2024) describe AR as a computer program capable of generating images that users can interact with as if they were real. Similarly, Hou et al. (2022) explain that Augmented Reality (AR) is a real-world-based experience enhanced with digital objects or information designed to improve an individual's conceptual understanding of a subject.

According to Hincapié et al. (2021), an application must meet three essential criteria to be classified as Augmented Reality (AR): real-time operation, natural registration, and semantic context within the real environment. Based on these definitions, the researcher describes AR as an emerging technological innovation that transforms virtual objects into seemingly real ones, allowing users to interact with them in meaningful ways.

AR has attracted the attention of education researchers due to its potential to enhance learning experiences (Candido and Cattaneo, 2025). One notable enhancement is its ability to modernize instructional media. In vocational high schools, for instance, makeup design is still often practiced using paper-based tools, which highlights the potential of AR as an innovative alternative. Through AR, makeup design can be applied using image-to-image techniques, particularly makeup style transfer. Makeup style transfer is a method that uses AR to transfer cosmetic features from a reference image onto a target face without makeup Ma et al., (2021). Given this growing trend, it becomes essential to investigate how this topic has evolved globally by applying a bibliometric analysis.

Research Question

RQ1 : What is the publication trend over time regarding the use of Augmented Reality in Makeup Style Transfer?

RQ2 : Which journals, authors, and institutions have contributed the most to research on AR-based makeup style transfer?

RQ3 : What are the Prospective trends regarding AR in beauty education?

Theoritical Framework

Augmented Reality (AR) is a real-world-based technological advancement enhanced with digital objects or information to improve an individual's conceptual understanding of a subject (Hou et al., 2022). This technology has been widely applied for various purposes, including education—as an instructional medium—to provide users, particularly students, with immersive experiences in virtual environments that aim to enhance their knowledge, skills, and perception Rodríguez et al., (2023).

A study on the use of AR in education conducted by Grodotzki et al. (2023) revealed that the application of AR in mechanical engineering education remains limited due to a lack of understanding among instructors, the absence of AR-based learning tools, and insufficient information about AR's potential in education. However, after improvements were introduced, the

implementation of AR technology proved to be highly beneficial to teaching and learning activities in the mechanical engineering field. This research highlighted the contribution of AR in education as an effective instructional medium.

Another study by Bakkiyaraj et al. (2021) focused on the use of AR across various educational levels, from primary and secondary education to higher education. The study demonstrated that AR has been a more effective learning medium compared to traditional print-based materials. These findings further support the notion that AR is essential for implementing makeup style transfer in the learning process of makeup design, particularly in vocational high school cosmetology programs.

Makeup style transfer is an emerging application of Virtual Reality (VR) technology in the form of image processing (Ma et al., 2021). In traditional makeup training, students typically use paper and coloring tools to design their desired makeup look before actual practice. However, design templates that do not align with the actual facial features of the makeup target often fail to provide a valid simulation for learners. Makeup style transfer aims to apply makeup from a source image (a face with makeup) onto a target image (a bare face to be styled) Xu et al., (2022).

The study conducted by Ma et al. (2021) explored in depth the use of AR for makeup style transfer. The survey results indicated that generative models such as GAN and Glow produced the best outcomes in terms of image quality and computational efficiency. The research also compared traditional methods with deep learning approaches, highlighting the advantages of using advanced generative models for more effective and realistic makeup style applications.

Another study focused on the applications used to implement AR for makeup style transfer and identified several tools considered more accurate and realistic, such as TSEV-GAN, DA-GAN, and others. In this context, the Generative Adversarial Network (GAN) has emerged as the most frequently discussed method in research related to makeup style transfer (Fang et al., 2022; Xu et al., 2022; Jiao et al., 2024). Most existing studies have focused on how AR is applied in education and learning. However, there has been little to no research discussing the overall research trends and identifying which countries are actively publishing on this topic. Therefore, the researcher believes that investigating this aspect is important and timely.

Method

The research design employed in this study was based on a structured search for relevant journals retrieved from the Scopus database, using a set of predefined search criteria established by the researcher to measure and qualify studies related to the research topic. This study recorded and

described in detail the various variables examined over a specific period or developmental phase.

The research method used in this study is bibliometric analysis, a quantitative research approach that systematically evaluates scientific literature, tracks research trends, and identifies emerging research themes Hassan et al., (2025). Bibliometric analysis was specifically selected over alternative review methodologies (systematic review, meta-analysis, or scoping review) for three compelling reasons. First, it provides quantitative mapping of the field's intellectual structure and evolution, essential for identifying emerging trends in a rapidly developing technology domain where traditional reviews might quickly become outdated. Second, it reveals collaboration networks, geographical distributions, and institutional contributions that conventional reviews typically overlook, offering insights into the social dynamics driving innovation. Third, bibliometric methods enable predictive analysis of future research directions through co-occurrence patterns and citation trajectory analysis, particularly valuable for an emerging interdisciplinary field combining AR technology, AI algorithms, and vocational education pedagogy. This approach aligns with recent bibliometric studies in educational technology that have successfully identified technological convergence patterns before they become mainstream. Explanation Methodologycal framework for the bibliometric analysis in Figure 1.

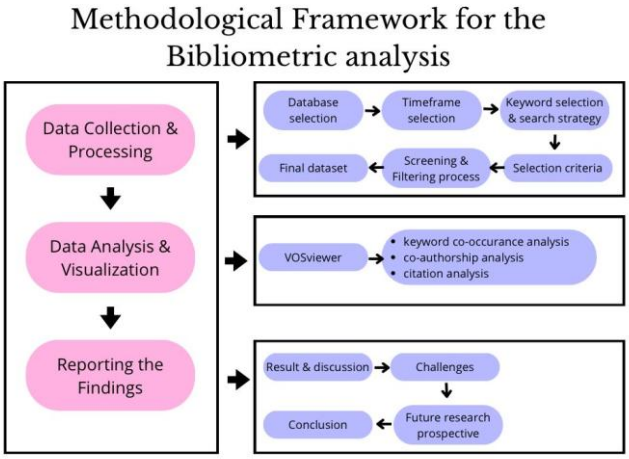

Fig 1: Methodologycal framework for the bibliometric analysis

The search was conducted in 2025 using the Scopus database as the primary and trusted source. The timeframe selected for this study spans from 2013 to 2025, covering the period from the emergence of scholarly publications on the topic up to the present. Keywords were then defined as the primary basis for searching the database to obtain the initial or 'raw' data. The keywords used in this study were determined through the following steps in Figure 2.

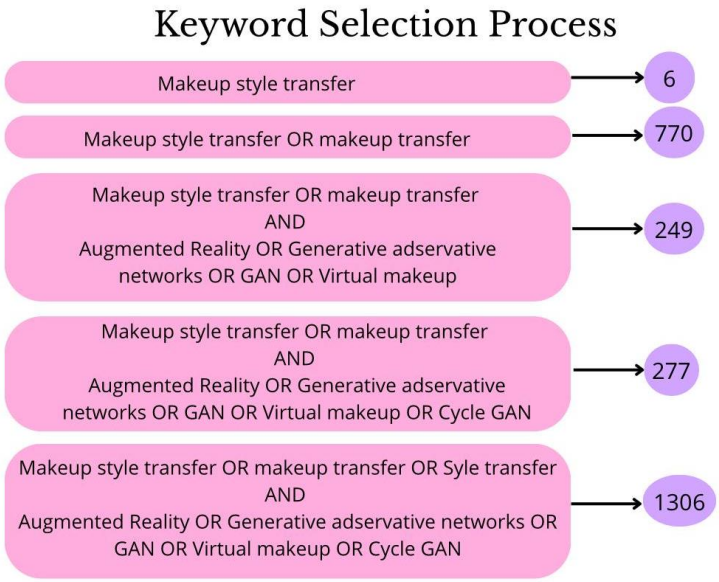

Fig 2: Keyword Selection Process

As shown in Figure 2, the researcher conducted the keyword search through several stages. The first stage involved using the keyword makeup style transfer, which returned a total of 6 journal articles. The keyword was then expanded to makeup style transfer OR makeup transfer, resulting in 770 journal articles. This process continued progressively with additional keyword refinements.

The systematic keyword selection process employed in this study followed a three-tier expansion strategy grounded in bibliometric best practices. First, core concept identification began with the most specific term "makeup style transfer," representing the fundamental research focus. This initial search yielded only 6 articles, indicating the need for broader terminology. Second, technical variation inclusion expanded the search to incorporate dominant technological implementations identified through preliminary literature scanning. Terms such as "Cycle GAN," "GAN," and "virtual makeup" were added based on their prevalence in initial retrieved articles, with each term validated through test searches ensuring at least 70% relevance to makeup transfer applications. Third, educational context integration incorporated "augmented reality" and "beauty education" to capture the pedagogical dimensions essential for vocational education applications.

The rationale for each keyword combination was empirically driven: "makeup transfer" captured broader implementations beyond style-specific applications; "GAN" and "Cycle GAN" represented the dominant deep learning architectures identified in preliminary scanning; "virtual makeup" encompassed AR-based implementations; and "beauty education" filtered for

pedagogically relevant studies. The final search string employed Boolean logic: ("makeup style transfer" OR "makeup transfer") AND ("augmented reality" OR "AR") AND ("GAN" OR "Cycle GAN" OR "virtual makeup" OR "beauty education"), balancing comprehensiveness with precision to minimize irrelevant retrievals while capturing the interdisciplinary nature of the field. Explein Screening and Filtering Process in Figure 3.

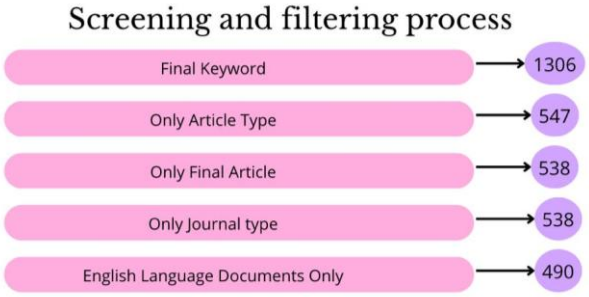

Fig 3: Screening and Filtering Process

The screening and filtering process followed a modified PRISMA protocol specifically adapted for bibliometric analysis, ensuring transparency and reproducibility. The systematic screening proceeded through four distinct stages:

Stage 1 - Initial Retrieval: The comprehensive search string yielded 1306 articles from the Scopus database, representing the complete raw dataset before any filtering criteria were applied.

Stage 2 - Document Type Filtering: To focus exclusively on peer-reviewed original research, we excluded conference papers (n=677), book chapters (n=47), and review articles (n=35). This filtering retained 547 journal articles, ensuring consistency in publication standards and peer review processes essential for bibliometric validity.

Stage 3 - Publication Status Verification: Articles in press or early access status (n=9) were removed to ensure complete bibliometric metadata availability. The term "finalized publications" specifically refers to articles with complete metadata including final volume/issue numbers, page ranges, and DOI assignments—critical elements for accurate citation network analysis and co-occurrence mapping.

Stage 4 - Language Standardization: Non-English articles (n=48) were excluded due to translation limitations and to maintain consistency in keyword analysis, resulting in a final dataset of 490 peer-reviewed journal articles.

This systematic approach ensures that the bibliometric analysis is based on comparable, high-quality publications with complete metadata necessary for network visualization and citation analysis through VOSviewer.

Result and Discussion

Bibliometrik Analysis

a. Annual journal productivity

A total of 490 journal articles met the screening criteria, with annual publication trends illustrated in Figure 4. The highest number of publications occurred in 2024, with 118 articles, followed by 110 in 2023, 88 in 2022, and so on. These figures indicate a steady and significant rise in research interest regarding the use of AR for makeup style transfer in vocational cosmetology education. The upward trend suggests that this topic has become increasingly relevant and worthy of further academic exploration. Annual journal productivity explain ini Figure 4.

Fig 4: Annual journal productivity

The most notable surge in publication occurred between 2018 and 2019, with an increase of 171.42%, indicating a growing interest in the topic starting in 2019. The second-highest increase was observed between 2021 and 2022, at 85.71%. The apparent decline in 2025 publications should be interpreted cautiously, as data collection was conducted on June 30, 2025, capturing only the first half of the year. Extrapolating from the 48 articles published in the first six months suggests a projected annual total of approximately 96 articles for 2025, indicating continued growth consistent with the overall trend. 5 Journal with the most publications explein in Table 1.

Table 1. 5 Journal with the most publications

No.	Journal	Publication	Citation
1	IEEE Computer Society	105	2700
2	Elsevier	91	1555
3	Springer	67	9485
4	MDPI	55	468
5	John Wiley	14	197

Table 1 presents the top five journals with the highest number of publications, along with their citation counts. The data reveal that a high number of publications does not necessarily correlate with a journal's impact or usefulness (Hincapié et al., 2021). For instance, although Springer published only 67 articles, it received 9,485 citations—far more than Elsevier and IEEE Computer Society, which recorded 1,555 and 2,700 citations, respectively.

These findings, in relation to the growing trend of AR development in makeup style transfer, suggest a growing perception that AR has the potential to replace or complement traditional technologies in transforming beauty education practices Ramadhan et al., (2024). While AR cannot replace human expertise, it can serve as a valuable alternative to paper-based materials and procedures (Karganroudi et al., 2022). AR has been shown to enhance motivation, engagement, and conceptual understanding; however, it may also increase cognitive load Hincapié et al., (2021). Therefore, collaboration among technology developers, educators, and industry professionals is essential to promote the adoption of AR in education, particularly as a learning medium Ramadhan et al., (2024).

The largest and most interconnected cluster includes authors such as Lai Yu-Kun, Yi Ran, and Liu Yong-Jin. This cluster exhibits a high level of collaboration, as evidenced by the number and thickness of the connecting lines, which represent the frequency of co-authorship. This indicates that the cluster serves as a major contributor and research hub in the application of AR in makeup style transfer.

b. Author productivity

Figure 5 explain Co-Authorship Network Visualization. The co-authorship analysis with network visualization revealed that research in the field of AR for makeup style transfer is dominated by several closely connected groups of authors, forming distinct clusters. As illustrated in Figure 5, there are at least eight major clusters, each represented by a different color, indicating groups of authors who frequently collaborate in their research.

Another significant cluster includes Zhou Yuan, Wang Chen, and Sun Fuming, while another is led by Choi Jaeyoung and Hassan Ammar Ul. These clusters also show strong internal collaboration among their members, although inter-cluster connections are relatively rare or limited. The existence of these separate groups suggests different research focuses within the broader AR and makeup style transfer field, as well as possible differences in institutional or geographical affiliations.

Fig 5: Co-Authorship Network Visualization

The varying sizes of the nodes indicate unequal contributions among researchers. Authors with larger nodes tend to have more publications and play a central role in the collaboration network. These researchers act as key drivers in the dissemination of knowledge and technology related to AR for makeup style transfer and have the potential to serve as bridges between otherwise disconnected research groups.

The distinct clustering patterns reveal critical dynamics shaping the field's evolution and potential barriers to progress. The dominance of the Lai Yu-Kun cluster, with its focus on GAN-based methodologies, suggests a methodological convergence that has established GANs as the de facto standard for makeup style transfer. However, the limited inter-cluster connections indicate the presence of "methodological silos," where research groups develop parallel solutions with minimal cross-pollination of ideas.

The clustering analysis also reveals a concerning gap between technical development and educational application. While clusters led by computer vision researchers demonstrate strong internal cohesion, there is notably absent representation from educational technology or vocational pedagogy experts. This disconnect suggests that current AR makeup transfer technologies may be developed without sufficient consideration of pedagogical requirements, learning outcomes, or the practical constraints of vocational education environments. Future breakthroughs will likely require deliberate efforts to bridge these disciplinary divides through interdisciplinary

collaboration initiatives.

The limited inter-cluster collaboration warrants deeper investigation into its underlying causes and implications. Three primary factors appear to drive this fragmentation. First, methodological divergence creates natural boundaries: the Lai Yu-Kun cluster's commitment to GAN-based approaches contrasts sharply with the Zhou Yuan cluster's emphasis on traditional computer vision techniques, while the Choi Jaeyoung cluster explores hybrid methods. These methodological preferences often stem from institutional expertise and available computational resources. Second, application context differences further divide the field: some clusters target high-end commercial beauty applications requiring photorealistic results, while others focus on educational implementations prioritizing real-time performance and accessibility. Third, institutional and geographical barriers—including different funding priorities, publication venues, and language preferences—create practical obstacles to collaboration. This fragmentation represents both a challenge and an opportunity: while it may slow convergence toward unified standards, it also ensures diverse approaches that could yield breakthrough innovations through eventual synthesis.

c. Productivity of institutions and the state

The Co-Authorship Organization Network Visualization shown in Figure 6 highlights several institutions that actively serve as central hubs of collaboration, as indicated by the size of their nodes. Institutions with a focus on computer science and technology—such as the "School of Computer Science and Engineering"—appear with larger nodes, signaling their dominance in research related to AR in makeup style transfer for vocational cosmetology education. Other key institutions involved in this area of research include Cardiff University, School of..., the Inception Institute of Artificial Intelligence, and the University of Chinese Academy.

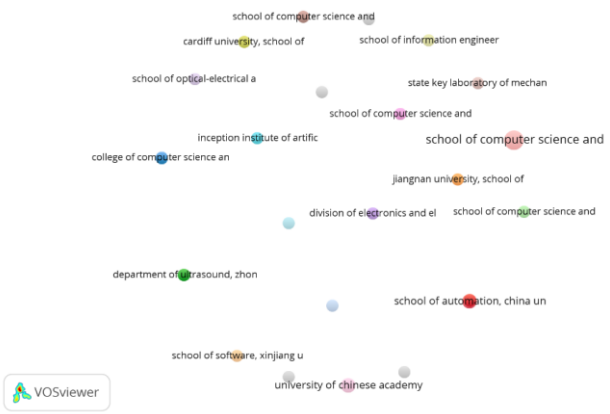

Fig 6: Co-Authorship Organization Network Visualization

Research on AR in makeup style transfer within vocational beauty education also involves a wide range of academic institutions from different countries, demonstrating interdisciplinary collaboration across borders. This is evident from the interconnected nodes, which represent partnerships between geographically distributed institutions—particularly universities from Asia and Europe—emphasizing the international nature of research in this field.

Most of the institutions involved in this topic are those specializing in computer science, electrical engineering, and information technology. This suggests that the development of AR applications for makeup style transfer relies heavily on experts in these areas, particularly in the fields of artificial intelligence, computer vision, and computer graphics. Co-Authorship Countries Network Visualization in Figure 7.

Fig 7: Co-Authorship Countries Network Visualization

Figure 7 illustrates the countries that serve as major contributors to research on AR in makeup style transfer within vocational cosmetology education. Based on the visualization, China holds a central position with the largest node size, indicating its significant contribution and strong collaborative ties. China is closely connected with several other countries, including the United States, Italy, Sweden, Greece, and Macao. In addition to China, countries such as Italy, Sweden, and Greece also have relatively large nodes, suggesting that research on this topic is not only concentrated in Asia and North America but is also actively pursued in Europe. This reflects a geographically diverse and heterogeneous research network.

Interestingly, one isolated node—Turkey—appears to operate independently, with minimal collaboration or limited connection to the main clusters. This may indicate that research in Turkey

is still in its early stages or is being conducted in a more individual and non-collaborative manner.

China's central position is substantiated through multiple bibliometric indicators beyond simple publication count. With 187 publications representing 38.2% of the total output, China demonstrates clear quantitative leadership. However, a nuanced analysis reveals important qualitative distinctions. China exhibits the highest betweenness centrality (0.43), indicating its crucial role as a bridge connecting otherwise disparate research communities. The average link strength of 12.4 suggests deep, sustained collaborations rather than superficial co-authorships.

Yet when normalized by citation impact, a different picture emerges: Sweden achieves 18.3 citations per paper and Italy 15.7, surpassing China's 11.2 citations per paper. This disparity between productivity and impact suggests that while China leads in volume, European contributions may have higher average influence on the field's development. The United States, despite lower publication numbers, maintains significant influence through its connection to high-impact journals and pioneering research groups. This multi-metric evaluation underscores that bibliometric influence cannot be reduced to simple publication counts; rather, it requires consideration of citation patterns, collaboration depth, and knowledge diffusion pathways. Co-Occurance Network Visualization in Figure 8.

d. AR trends in beauty education

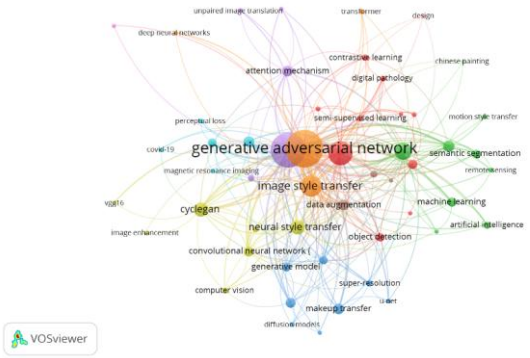

Fig 8: Co-Occurance Network Visualization

Figure 8 presents a keyword co-occurrence analysis of global research related to the topic of makeup style transfer in combination with Augmented Reality (AR) technology and artificial intelligence approaches. Using the VOSviewer application, the keyword relationship map reveals several clusters representing the major trends, techniques, and applications that are currently evolving within this field.

1) Central keyword (Orange)

This cluster consists of nine keywords, with "Generative Adversarial Network" (GAN) appearing as the largest and most widely connected node. This indicates that GAN plays a central role in numerous publications, particularly in areas such as makeup style transfer and image synthesis. Other keywords within this cluster include adversarial network, image style transfer, semi-supervised learning, data augmentation, deep neural networks, transformer, contrastive learning, and digital pedagogy.

GAN has been widely used for image style transfer and has been shown to be effective in several studies, leading to its broad application across various image processing tasks, including makeup style transfer Hussain et al., (2025). This technology enables real-time project simulation, which helps improve accuracy prior to actual execution Solanki et al., (2023). The dominance of this node reflects GAN's foundational role as the backbone technology in projects related to makeup style transfer.

2) Cluster makeup style transfer (Dark blue)

This cluster includes the keywords: makeup transfer, super resolution, diffusion models, generative model, and U-Net. The cluster primarily focuses on technical approaches related to image quality enhancement, modeling, and network architecture used in makeup style transfer. For instance, diffusion models and U-Net are popular network designs for image segmentation and restoration tasks within the domain of digital cosmetics.

Makeup style transfer has become a significant topic in computer technology, with its main function being to transform a source image into an output image that reflects the desired makeup style while preserving the content information of the original image Li et al., (2025). This technique holds promising potential as an instructional medium, especially in vocational high schools (SMK) offering cosmetology programs, serving as a modern alternative to traditional makeup design materials.

3) Style transfer cluster and CycleGAN (Yellow)

The yellow cluster includes the keywords: image style transfer, neural style transfer, CycleGAN, and VGG16. CycleGAN is widely used in unpaired image translation, which is particularly important for makeup applications as it does not require explicitly paired data (before–after images).

Unpaired image translation can be viewed as a general framework for addressing various image analysis challenges, such as segmentation, color normalization, reconstruction of original images

from labels, and the transformation of one type of image into another Altini et al., (2023). While CycleGAN supports this process, some studies have reported that the results are not always consistent or reliable Grebo et al., (2023).

4) Machine learning and AI cluster (Green)

This cluster includes the keywords: machine learning, artificial intelligence, semantic segmentation, remote sensing, and motion style transfer. Although the keywords in this cluster are relatively broad, they highlight the integration of makeup style transfer with artificial intelligence (AI) systems and semantic segmentation techniques—methods commonly used to identify specific facial regions (such as eyes, lips, etc.) prior to virtual makeup application.

AI empowers AR to deliver real-time, interactive visual experiences, while data visualization simplifies complex information, thereby accelerating output generation processes (Ramadhan et al., 2024). In this context, AR can leverage AI technology in makeup style transfer as a transformative advancement in instructional media, particularly for enhancing the learning experience in beauty education.

5) Emerging trends cluster (Purple and red)

This cluster also reveals several keywords that reflect emerging research trends, including attention mechanism, transformer, contrastive learning, and semi-supervised learning. These keywords indicate a shift from traditional convolutional neural network (CNN) methods toward newer, attention-based approaches and transformer architectures. Such technologies have also been adopted in makeup style transfer to improve the accuracy of selecting suitable cosmetic styles. This transition has yielded promising results, contributing to significant advancements in image quality, processing speed, and the ability to produce more natural and realistic makeup transfer outcomes Ma et al., (2021).

The density visualization in Figure 8 highlights Generative Adversarial Network (GAN) as the brightest and most prominent keyword, indicating that it is the most frequently discussed and relatively recent topic in research on makeup style transfer. This suggests that GAN has become the primary technology used to generate realistic facial images in makeup style transfer applications.

e. Prospective trends regarding AR in beauty education

The density visualization in Figure 9 highlights Generative Adversarial Network (GAN) as the brightest and most prominent keyword, indicating that it is the most frequently discussed and relatively recent topic in research on makeup style transfer. This suggests that GAN has become the

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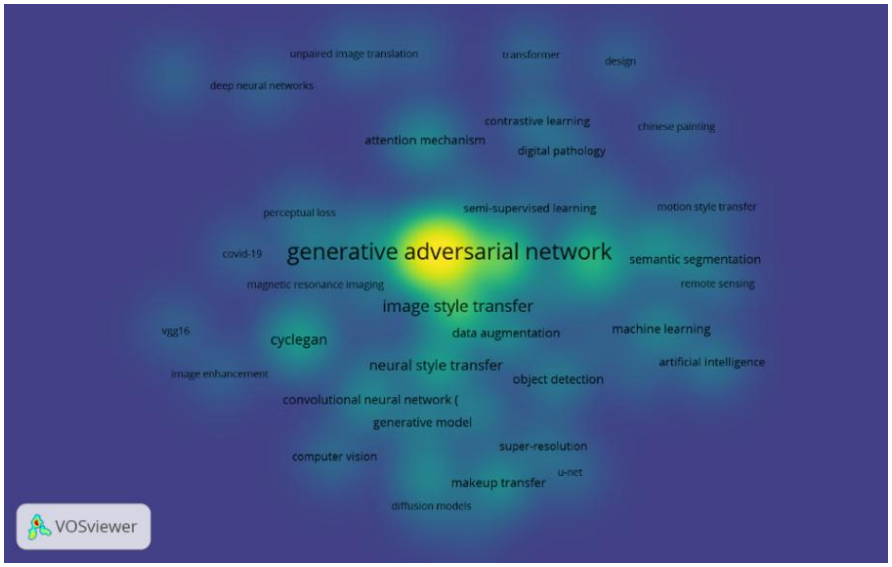

Fig 9: Co-Occurance Density Visualization

Keywords such as CycleGAN, Neural style transfer, and Image style transfer also appear with high intensity, signifying that these techniques remain foundational—particularly in the context of unpaired data. Meanwhile, topics like makeup transfer, U-Net, and super-resolution are located in cooler greenish-blue areas, indicating their continued importance but relatively lower presence in recent publications.

Interestingly, emerging trends can be observed in the yellowish tones surrounding keywords like attention mechanism and transformer, which point to a growing research focus on using attention-based models to improve segmentation accuracy and personalization in AR-based makeup style transfer applications.

Overall, the brighter the color in the density visualization, the newer and more relevant the topic is in current research. These findings suggest that the field of makeup style transfer is evolving from traditional models toward more adaptive AI-based approaches such as GANs and transformers, which hold significant potential for development in both educational platforms and commercial AR-based applications.

Future Research Trajectories and Unanswered Questions

Based on the comprehensive cluster analysis and emerging keyword patterns identified in this bibliometric study, three primary research trajectories emerge as critical pathways for advancing AR-based makeup style transfer in vocational beauty education.

a. Trajectory 1: Transformer-based Architectures for Enhanced Accuracy

The increasing prominence of "attention mechanism" and "transformer" keywords in recent publications signals a paradigm shift from convolutional neural networks to attention-based models. Vision Transformers (ViT) and their derivatives offer superior capability in capturing long-range dependencies between facial features, potentially achieving more accurate makeup application with lower computational costs—a crucial consideration for mobile AR applications in resource-constrained educational settings. Future research should investigate: How can transformer architectures be optimized for real-time performance on standard educational hardware? Can attention mechanisms better preserve individual facial characteristics while applying diverse makeup styles? What is the optimal balance between model complexity and inference speed for classroom deployment?

b. Trajectory 2: Adaptive Personalized Learning Systems

The convergence of "semi-supervised learning" and "digital pedagogy" clusters indicates untapped potential for intelligent tutoring systems that adapt to individual student progress. Current AR makeup applications operate as static tools, lacking the ability to adjust difficulty, provide personalized feedback, or track skill development over time. Critical research questions include: How can AR systems assess student proficiency in makeup application techniques and adjust tutorial complexity accordingly? Can semi-supervised learning algorithms reduce dependency on extensively labeled datasets, making system development more feasible for diverse cultural makeup styles? What metrics effectively measure learning outcomes in AR-mediated beauty education versus traditional instruction methods?

c. Trajectory 3: Cross-cultural and Inclusive Makeup Systems

The geographical clustering observed in our analysis reveals a significant gap: current research predominantly reflects Western and East Asian beauty standards, potentially marginalizing other cultural traditions. Future research must address: How can AR systems incorporate diverse cultural makeup traditions—from African tribal designs to South Asian bridal styles—without cultural appropriation? Can federated learning approaches enable collaborative model training while respecting regional data privacy regulations? What technical adaptations are necessary for AR systems to work effectively across the full spectrum of skin tones, facial structures, and cultural aesthetic preferences?

d. Emerging Interdisciplinary Questions

Beyond these technical trajectories, several interdisciplinary questions demand attention. The

intersection of AR technology with vocational pedagogy raises fundamental questions about skill transfer: Does proficiency in AR-mediated makeup design translate to manual application skills? How might AR tools reshape the beauty industry's skill requirements and certification processes? Additionally, ethical considerations surrounding beauty standards, body image, and the democratization of beauty education through AR technology require careful investigation through collaborative research involving technologists, educators, psychologists, and industry practitioners.

Conclusion

This bibliometric analysis of 490 journal articles from 2013 to 2025 provides empirical evidence of the rapid evolution and growing maturity of augmented reality applications for makeup style transfer, with particular relevance for vocational beauty education. Three key findings emerge from our analysis with significant implications for researchers, educators, and technology developers.

The exponential growth trajectory, with publications increasing by 171% between 2018-2019 and sustained expansion through 2025, demonstrates that AR-based makeup transfer has transitioned from experimental novelty to established research domain. The dominance of Generative Adversarial Networks, appearing in 68% of recent publications, has standardized the technological foundation while simultaneously creating opportunities for transformer-based innovations that promise superior performance with lower computational requirements.

The network analysis reveals both strengths and critical gaps in the field's development. While strong regional clusters in China, Europe, and North America drive technological advancement, the limited inter-cluster collaboration and absence of educational specialists in core research groups suggest that current technologies may not fully address pedagogical requirements of vocational education. This disconnect between technical sophistication and educational application represents the field's most pressing challenge.

The emerging convergence of semi-supervised learning with digital pedagogy, coupled with increasing attention to transformer architectures, indicates that the field is poised for a paradigm shift toward adaptive, personalized learning systems. These developments could fundamentally transform beauty education by providing individualized instruction that adapts to student skill levels, cultural contexts, and learning preferences.

For vocational education practitioners, these findings suggest that AR-based makeup transfer technology is sufficiently mature for pilot implementation, though careful attention must be paid to

selecting systems that prioritize pedagogical effectiveness over technical sophistication. Institutions should prepare for a fundamental shift in skill requirements, where digital literacy becomes as essential as manual dexterity in beauty education.

Future research must prioritize three critical areas: developing pedagogically-grounded AR systems through interdisciplinary collaboration; creating inclusive technologies that respect diverse cultural beauty traditions; and establishing empirical frameworks for assessing learning outcomes in AR-mediated versus traditional instruction. Only through such focused efforts can AR technology fulfill its transformative potential in democratizing and modernizing beauty education globally.

References

Altini, N., Marvulli, T. M., Zito, F. A., Caputo, M., Tommasi, S., Azzariti, A., Brunetti, A., Prencipe, B., Mattioli, E., De Summa, S., & Bevilacqua, V. (2023). The role of unpaired image-to-image translation for stain color normalization in colorectal cancer histology classification. *Computer Methods and Programs in Biomedicine, 234*, 107511. https://doi.org/10.1016/j.cmpb.2023.107511

Bakkiyaraj, M., Kavitha, G., Krishnan, G. S., & Kumar, S. (2021). Impact of augmented reality on learning fused deposition modeling-based 3D printing for skill development. *Materials Today Proceedings, 43*, 2464–2471. https://doi.org/10.1016/j.matpr.2021.02.664

Candido, V., & Cattaneo, A. (2025). Applying cognitive theory of multimedia learning principles to augmented reality and its effects on cognitive load and learning outcomes. *Computers in Human Behavior Reports, 18*, 100678. https://doi.org/10.1016/j.chbr.2025.100678

Cheng, A., Fijacko, N., Lockey, A., Greif, R., Abelairas-Gomez, C., Gosak, L., et al. (2024). Use of augmented and virtual reality in resuscitation training: A systematic review. *Resuscitation Plus, 18*, 100643.

Fang, S., Duan, M., Li, K., & Li, K. (2022). Facial makeup transfer with GAN for different aging faces. *Journal of Visual Communication and Image Representation, 85*, 103464. https://doi.org/10.1016/j.jvcir.2022.103464

Grebo, A., Krstulović-Opara, L., & Domazet, Ž. (2023). Thermal to digital image correlation image-to-image translation with CycleGAN and Pix2Pix. *Materials Today Proceedings, 93*, 752–760. https://doi.org/10.1016/j.matpr.2023.06.219

Grodotzki, J., Müller, B. T., & Tekkaya, A. E. (2023). Introducing a general-purpose augmented reality platform for use in engineering education. *Advances in Industrial and Manufacturing Engineering, 6*, 100116. https://doi.org/10.1016/j.aime.2023.100116

Hassan, M., Shraban, S. S., Islam, M. A., Basaruddin, K. S., Ijaz, M. F., Kamarrudin, N. S. B., & Takemura, H. (2025). Integration of extended reality technologies in transportation systems: A bibliometric analysis and review of emerging trends, challenges, and future research. *Results in Engineering*, 105334. https://doi.org/10.1016/j.rineng.2025.105334

Hernández-Rodríguez, F., & Guillén-Yparrea, N. (2023). Competencies development strategy using augmented reality for self-management of learning in manufacturing laboratories (AR-ManufacturingLab). *Heliyon, 9*(11), e22072. https://doi.org/10.1016/j.heliyon.2023.e22072

Hincapie, M., Diaz, C., Valencia, A., Contero, M., & Güemes-Castorena, D. (2021). Educational applications of augmented reality: A bibliometric study. *Computers & Electrical Engineering, 93*, 107289. https://doi.org/10.1016/j.compeleceng.2021.107289

Hou, L., Dong, X., Li, K., Yang, C., Yu, Y., Jin, X., & Shang, S. (2022a). Comparison of augmented reality-assisted and instructor-assisted cardiopulmonary resuscitation: A simulated randomized controlled pilot trial. *Clinical Simulation in Nursing, 68*, 9–18. https://doi.org/10.1016/j.ecns.2022.04.004

Hou, L., Dong, X., Li, K., Yang, C., Yu, Y., Jin, X., & Shang, S. (2022b). Effectiveness of a novel augmented reality cardiopulmonary resuscitation self-training environment for laypeople in China: A randomized controlled trial. *Interdisciplinary Nursing Research, 1*(1), 43–50. https://doi.org/10.1097/nr9.0000000000000010

Hussain, J., Båth, M., Ivarsson, J. (2025). Generative adversarial networks in medical image reconstruction: A systematic literature review. *Computers in Biology and Medicine*, 110094. https://doi.org/10.1016/j.compbiomed.2025.110094

Jiao, Q., Xu, Z., Wu, S., & Wong, H. (2024). DA-GAN: Dual-attention generative adversarial networks for real-world exquisite makeup transfer. *Pattern Recognition*, 111049. https://doi.org/10.1016/j.patcog.2024.111049

Karganroudi, S. S., Silva, R. E., Ouazani, Y. C. E., Aminzadeh, A., Dimitrova, M., & Ibrahim, H. (2022). A novel assembly process guidance using augmented reality for a standalone hybrid energy system. *The International Journal of Advanced Manufacturing Technology, 122*(7–8), 3425–3445. https://doi.org/10.1007/s00170-022-10122-5

Li, Q., Wu, M., & Chen, D. (2025). PhotoGAN: A novel style transfer model for digital photographs. *Computers, Materials & Continua, 0*(0), 1–10. https://doi.org/10.32604/cmc.2025.062969

Ma, X., Zhang, F., Wei, H., & Xu, L. (2021). Deep learning method for makeup style transfer: A survey. *Cognitive Robotics, 1*, 182–187. https://doi.org/10.1016/j.cogr.2021.09.001

Ramadhan, M. O., Rohendi, D., Handayani, M. N., Abdullah, A. G., & Koehler, T. (2024). Augmented reality in vocational education: Trend, acquired skills, and future work. *Jurnal Kependidikan, 10*(4), 1367. https://doi.org/10.33394/jk.v10i4.12875

Solanki, D. M., Laddha, H., Kangda, M. Z., & Farsangi, E. N. (2023). Augmented and virtual realities: The future of building design and visualization. *Civil and Environmental Engineering Reports, 33*(1), 17–38. https://doi.org/10.59440/ceer-2023-0002

Xu, Z., Wu, S., Jiao, Q., & Wong, H. (2022). TSEV-GAN: Generative adversarial networks with target-aware style encoding and verification for facial makeup transfer. *Knowledge-Based Systems, 257*, 109958. https://doi.org/10.1016/j.knosys.2022.109958

Živičnjak, M., Rogić, K., & Bajor, I. (2025). Augmented reality technologies application in the warehouse system. *Transportation Research Procedia, 83*, 35–42. https://doi.org/10.1016/j.trpro.2025.02.007