INSTITUTO UNIVERSITÁRIO EGAS MONIZ

MESTRADO INTEGRADO EM CIÊNCIAS FARMACÊUTICAS

THE RISE OF ARTIFICIAL INTELLIGENCE IN SKIN CARE: UNLOCKING PRODUCT INNOVATION IN COSMETIC DERMATOLOGY

Trabalho submetido por
Marine Oksana Alice Georges
para a obtenção do grau de Mestre em Ciências Farmacêuticas

julho de 2025

EGAS MONIZ SCHOOL of HEALTH & SCIENCE | INSTITUTO UNIVERSITÁRIO EGAS MONIZ

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ABSTRACT

In the last decade, artificial intelligence (AI) has played a key role in driving significant scientific and commercial advancements in the field of skin cosmetics. AI is nowadays a powerful tool within the cosmetic product lifecycle – ranging from screening of new raw materials, to the prediction of their efficacy and safety profile. Furthermore, AI also provides a data-driven, objective recommendation to both practitioners and patients, thus enhancing the accuracy and personalization of treatments, this however should be carefully considered and interpreted. As the global Cosmetics Market size is valued at 270.68 billion of euros in 2022, and is projected to reach 432.25 billion of euros by 2030, there is an increasing demand for the development of new cosmetics that address consumer needs, as well as the development of suitable worflows that warrant product aquisition. In this context, this thesis will focus on: (i) The emerging role of AI in skin assessment and diagnostic, with a special focus on market-available AI devices for professionals, as well as for the public in general; (ii) Its application in providing patient-specific cosmetic product recommendations and finally, (iii) The main ethical and regulatory challenges associated with the integration of this technology in cosmetology. Throughout the work, particular emphasis is given to the evolving role of pharmacists, who are increasingly called upon to interpret AI-generated results and guide patients in the aquisition of cosmetic products. To integrate these concepts into a real-case study, L'Oréal's AI-powered tools will be described. These include ModiFace, SkinConsult AI and Perso. Their main features will be detailed to illustrate the already real and practical application of AI, as a powerfull tool in skincare personalization, but also as an enhancing promotor of consumer experience.

The integration of AI in the cosmetic industry marks a major step forward in skin care personalization, while improving process efficiency.

Keywords: Artificial intelligence, Cosmetic Dermatology, Personalized Skincare, Cosmetic market.

RESUMO

Na última década, a inteligência artificial (IA) tem vindo a desempenhar um papel fundamental no avanço cientifico e comercial de produtos cosméticos para a pele. A IA é atualmente uma ferramenta relevante em várias etapas do desenvolvimento de produtos cosméticos, desde o *screening* de novos compostos, até á previsão do perfil de eficácia e segurança de um dado produto. Adicionalmente, uma das áreas que têm vindo a ser alvo de um crescente desenvolvimento, refere-se à integração da IA no diagnóstico e na recomendação de produtos. Esta integração resulta na disponibilização de informação que pode prontamente ser utilizada pelo público, e também pelos profissionais de saúde, o que pode acarretar alguns desafios. Em 2022, a indústria cosmética estava avaliada globalmente em 270,68 mil milhões de euros, no entanto projeta-se o seu crescimento para 432,25 mil milhões de euros até 2030. Com base neste intenso dinamismo económico, torna-se imperativo o desenvolvimento mais célere de novos produtos cosméticos, que correspondam às necessidades dos consumidores, e consequentemente o desenvolvimento de mecanismos que facilitem o seu escoamento. Com base neste panorama, esta tese pretende explorar: (i) O papel da IA no campo da biometria cutânea e no diagnóstico, com um especial ênfase nos vários dispositivos de IA disponíveis; (ii) A aplicação da IA na recomendação personalizada de produtos cosméticos e finalmente; (iii) Quais os desafios éticos e regulamentares que podem advir da integração desta tecnologia na prática da cosmetologia. Ao longo da presente tese é também detalhado o papel emergente do farmacêutico nesta área, uma vez que por ser um profissional de saúde com grande proximidade com a população, é muitas vezes chamado, e prevê-se empiricamente que esta tendência se torne cada vez mais relevante, para interpretar resultados gerados por IA de forma a guiar o paciente na aquisição de produtos cosméticos adequados. De forma a integrar todos estes conceitos num caso-estudo, as ferramentas de IA da L'Oréal's, irão ser abordadas como súmula da tese. Estas incluem a ModiFace, SkinConsult AI e Perso. As principais características irão ser descritas de forma a sublinhar a respetiva aplicabilidade na personalização do aconselhamento de produtos cosméticos, como também na promoção de uma melhor experiência de compra para o consumidor.

A integração da IA na indústria cosmética marca um grande avanço na personalização dos cuidados com a pele, sendo também demarcado o seu papel na melhoria da eficiência do processo de compra dos produtos.

Palavras-chaves: Inteligência artificial, Dermatologia cosmética, Cuidados personalizados da pele, Mercado cosmético.

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ABBREVIATIONS

3D	Three-dimensional
AI	Artificial intellience
ANNs	Artificial Neural Networks
AR	Augmented reality
CNNs	Conventional Neural Networks
DL	Deep learning
ML	Machine Learning
MTCNN	Multi-Task Cascaded Convolutional Neural Network
NNs	Neural Networks
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
SVM	Support Vector Machines
TEWL	Transepidermal water loss
UK	United kingdom
US	United States of America
YOLO	You only look once
VTO	Virtual try on
PDPs	Product detail pages
PASI	Psoriasis Area and Severity Index

1. Introduction

1.1. The skin: Structure and functions

As the largest organ of the human body, the skin can represent around 16% of a person's total weight, covering between 1.7 to 2 square meters of surface area and weighing more than 4 kilograms (McGrath & Uitto, 2024). The skin is made up of three layers: the epidermis, dermis and hypodermis (Yousef H et al., 2024). Each layer has its own structure and function, as illustrated in Figure 1.

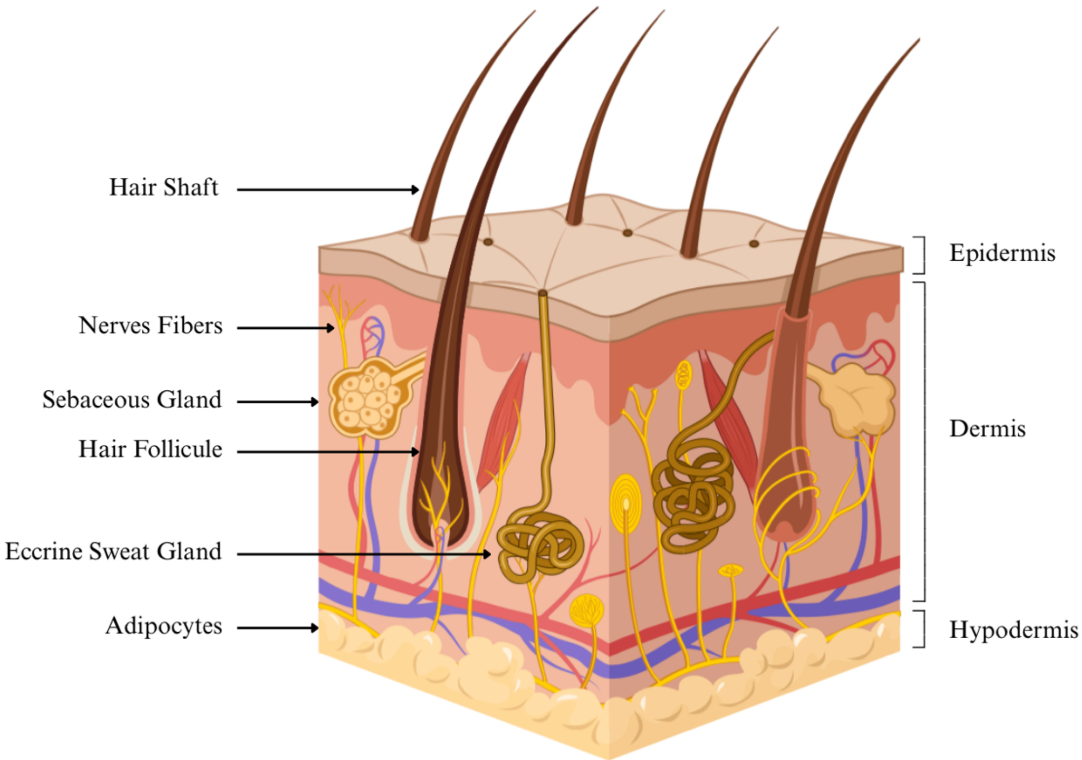


Figure 1: Layers of the skin and skin appendages (created using the BioRender program).

Far from being a simple outer layer, the skin functions as a dynamic and multifunctional barrier between the internal body systems and the external environment, protecting the body from pathogens such as viruses and bacteria, as well as from environmental stressors including infections, chemical and thermal stress, UV radiation and physical injuries (Yousef H et al., 2024).

Beyond its role as a protective barrier, the skin carries out multiple essential functions that contribute to maintaining homeostasis and supporting social interaction. It plays a key role in sensory perception, thermoregulation, immune defence, and metabolic activity. Sensory receptors detect pain, pressure, temperature and touch. Thermoregulation is managed by sweat glands; hair follicles and blood vessels that help regulate body temperature. In terms of immune defence, the skin hosts immune cells that detect pathogens and trigger protective responses. Its metabolic role, largely carried out in the hypodermis, includes vitamin D synthesis and lipid storage (Sanjay Agarwal & Karthik Krishnamurthy, 2024).

Skin thickness varies considerably across body regions, ranging from about 0.5 mm to 3 cm when including the epidermis, dermis, and hypodermis (Dermatol Venereol, 2005). These differences reflect the functional needs of each area. For example, the epidermis is extremely thin on the eyelids: less than 0.1 mm but reaches up to 1.5 mm on the palms and soles due to the stratum lucidum, an additional protective layer (Yousef H et al., 2024). The dermis also varies, being especially thick on the back: 30 to 40 times thicker than the overlying epidermis. In regions like the back, abdomen, palms and soles, a well-developed hypodermis further increases total skin thickness, enhancing protection and insulation (Kolarsick et al., 2011; Walters & Roberts, 2002).

These structural differences allow the skin to fulfil specialized roles. On the fingertips, for example, the skin is thick, sensitive, and slightly moist to enhance grip. Conversely, the eyelid skin is thin and flexible, enabling rapid movement while protecting the eye. (Mcknight et al., 2021). In addition, the skin includes several appendages that support its functioning, such as hair follicles, sweat ducts, sebaceous glands and nails (Kolarsick et al., 2011).

In the following paragraphs, the anatomical and histological organization of the skin will be detailed, focusing on its layered structure, cellular components, appendages, and main functions. This overview provides essential background for understanding the skin’s role and the importance of cosmetic products.

Epidermis:

As the skin's outermost layer, the epidermis serves as an initial barrier protecting the body from environmental aggressors. It is a stratified squamous epithelium primarily composed of keratinocytes, which make up most of its cells. These cells are responsible for producing keratin: a long, fibrous protein that plays a key protective role. In addition to keratinocytes, the epidermis also contains several other important cell types, including melanocytes, Langerhans cells and Merkel cells, as depicted in Figure 2. Each contributing to specific functions such as pigmentation, immune response and sensory perception (Kolarsick et al., 2011).

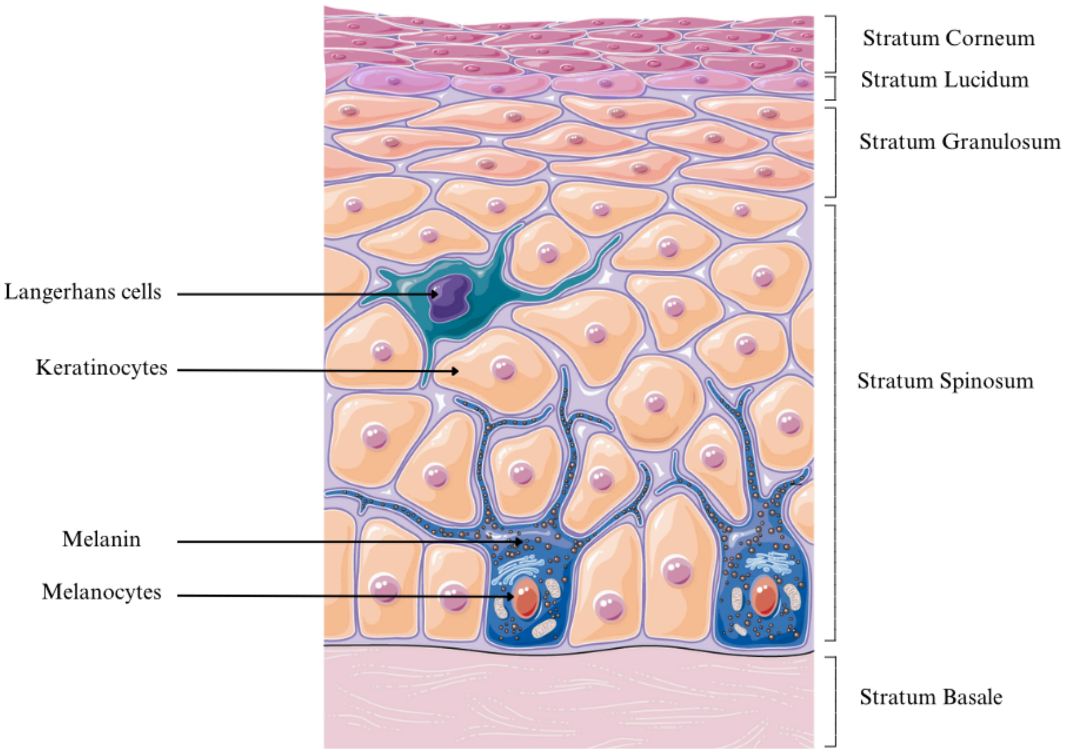


Figure 2: Epidermis layers, and respctives cells types (Image adapted from Smart Servier Medical Art).

From a histological perspective, the epidermis includes five distinct layers, classified based on keratinocyte morphology and their position within the tissue, as depicted in Figure 2: (i) stratum corneum; (ii) stratum lucidum; (iii) stratum granulosum; (iv) stratum spinosum and finally (v) stratum basale. Together, these layers form an effective shield against pathogens and environmental challenges (Dermatol Venereol, 2005).

The epidermis is a continuously renewing tissue that gives rise to structures such as hair follicles, sebaceous glands, nails and sweat glands. Its basal cells undergo regular proliferation cycles, ensuring a constant renewal of the outer layers. During this renewal process, basal cells migrate upward toward the skin's surface, interacting with other cell types such as melanocytes and Langerhans cells along the way (Kolarsick et al., 2011).

Dermis:

Situated directly beneath the epidermis, the dermis comprises a dense, collagen-rich connective tissue layer that gives the skin its structural framework and mechanical durability (Kolarsick et al., 2011a). It is composed of a complex network of fibrous, filamentous, and amorphous connective tissue, which houses blood vessels, lymphatic vessels, nerve endings and skin appendages such as sweat and sebaceous glands. These structures are essential for thermoregulation, immune defence, and skin hydration (Dermatol Venereol, 2005).

The dermis is primarily made up of collagen, a family of fibrous proteins produced by fibroblasts. Collagen is the main structural component of the dermis and plays a key role in providing strength, flexibility, and resistance to mechanical stress (Kolarsick et al., 2011). In fact, at least 15 genetically distinct types of collagens are found in human skin, and this protein is also a major constituent of tendons, ligaments, as well as bone linings. Although collagen fibers ensure strength under tension, elastic fibers also present, lend stretch and recoil. These elastic fibbers, however, have a limited capacity to resist tearing or over-deformation (Kolarsick et al., 2011).

Functionally, the dermis makes up the bulk of the skin and is responsible for its pliability, elasticity, and capacity to withstand mechanical forces. It retains water, helps to regulate body temperature, and contains receptors that detect sensory stimuli such as pressure and vibration. The dermis actively contributes to skin maturation and renewal. It interfaces with the epidermis to form the dermal-epidermal junction and supports appendageal growth: including hair follicles. In wound healing, the dermis and epidermis coordinate complex processes of tissue repair and remodelling (Kolarsick et al., 2011).

Hypodermis:

The hypodermis, also known as subcutaneous tissue, is the deepest layer of the skin. This deepest skin layer mainly consists of loose connective tissue and adipocytes (fat cells), which may form up to half of the body's fat. These cells are grouped in lobules and linked to the dermis by collagen and elastin fibbers. These adipocytes are organized into lobules and connected to the dermis through a network of collagen and elastin fibbers (Walters & Roberts, 2002). The hypodermis serves several key functions: thermal insulator, shock absorber and a major energy reserve. It also helps anchor the skin to the underlying structures, such as muscles, and supports the passage of blood vessels and nerves to the upper layers of the skin. In addition to adipocytes, the hypodermis contains fibroblasts and macrophages, which contribute to immune defence and structural maintenance (Sanjay Agarwal & Karthik Krishnamurthy, 2024).

Although not the central focus of this thesis, understanding the structures associated with the skin such as hair follicles, sebaceous glands, sweat glands and nails, is essential to appreciate the broader physiological context of the skin, that will ultimately be the basis of establishing skincare and dermatological innovation. Table 1 summarizes the key anatomical and functional features of skin appendages.

Skin Appendages:

Skin appendages are specialized structures originating from both the epidermis and dermis, including hair, nails, sweat glands and sebaceous glands. Each has distinct anatomical features, functions, and histological characteristics as previously illustrated in Figure 1 and Table 1 (Yousef H et al., 2024).

Table 1: Structure, function and cosmetic relevance of skin appendages. Adapted from (Yousef H et al., 2024).

Structure	Descriptions	Functions	Cosmetic Relevance
Hair	Formed of shaft and follicle, Anchored in dermis; Include infundibulum, isthmus and inferior segment	- UV Protection - Thermoregulation - Tactile sensation	Symbol of health and beauty, Focus of numerous cosmetic treatments (e.g. shampoos, hair growth, hair conditioner, hair mascara, hair dye, among others)
Sebaceous Glands	Holocrine glands connected to hair follicles; Secrete sebum via full cell disintegration	- Lubrication of skin and hair - Antimicrobial defence	Target in acne treatment: (e.g. Sebum-regulating products, mattifying creams, anti-acne cleansers, retinoid-based serums)
Eccrine Sweat Glands	Located across body (except lips/genitalia); Open directly onto skin surface	- Thermoregulation - Water and electrolyte balance - Skin hydration	Relevant in deodorants and hydration-based skincare (e.g. antiperspirant sprays, moisturizing gels, electrolyte-restoring mists)
Apocrine Sweat Glands	Found in axillae, areola, anogenital regions; Open into hair follicles; Activated at puberty	- Pheromonal communication - Odor production. -> Active after puberty	Relevant for deodorants/ antiperspirants; hygiene. (e.g. long-lasting deodorants, antibacterial roll-ons, odour-neutralizing wipes)
Nails	Keratinized plates covering fingertips and toes, Composed of nail plate, bed, matrix, folds	Protect fingertips/toes, Aid in fine motor skills, Reflect systemic health	Used in nail care and aesthetics, Indicators of health. (e.g. nail strengtheners, cuticle oils, nail polishes, biotin supplements)

As briefly addressed in the previous table, far from being limited to aesthetic purposes, cosmetics contribute to skin care, protection, and overall well-being. In a world increasingly focused on health, self-image, and prevention, these products have taken on a central role. The following section explores what defines a cosmetic product and its importance in modern society.

1.2. Cosmetic Industry Trends and Societal Impact

Cosmetics have been used for thousands of years, becoming an essential part of daily life without us even realizing it. From the toothpaste we reach for several times a day, to the soap used for handwashing, these products are everywhere and drive a vast industry. Today, most people depend on cosmetics and personal care items on a daily basis to support their health, improve their well-being, and enhance their self-confidence. According to Cosmetics Europe, these products can be grouped into seven categories, as listed in Figure 3 (The Personal Care Association, 2023).

Figure 3: Classification of cosmetic products. Adapted with Canva from (The Personal Care Association, 2023).

According to Regulation (EC) N° 1223/2009 of the European Parliament, the definition of a cosmetic is "any substance or mixture intended to be placed in contact with the external parts of the human body (epidermis, hair system, nails, lips and external genital organs) or with the teeth and the mucous membranes of the oral cavity with a view exclusively or mainly to cleaning them, perfuming them, changing their appearance, protecting them, keeping them in good condition or correcting body odours" (Official Journal of the European Union, 2009).

a) Major players and brands:

In 2023, the European cosmetic industry was valued approximately at 96 € billion, ranking among the largest markets in the world. However, the United States (US) market claimed the top spot with a value of 102 € billion, followed by China at 59 € billion. Other notable markets include Brazil at 24 € billion, Japan at 22 € billion, India at 13 € billion, and South Korea at 9 € billion. The economic market of cosmetics by geography is further illustrated in Figure 4 (The Personal Care Association, 2023).

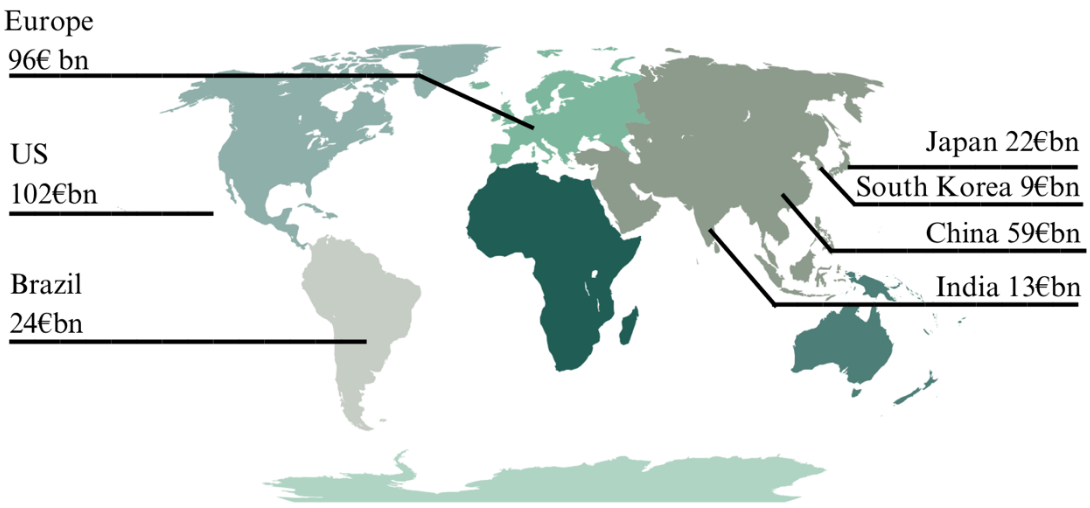


Figure 4: Global Market For Cosmetic Products (Image made with Canva).

Within Europe, Germany leads the cosmetics market with an estimated value of 14.3 € billion, followed by France (12.9 € billion), the United Kingdom (UK) (10.5€ billion), Spain (9.3 € billion) and Poland (4.5 € billion), as illustrated in Figure 5 (The Personal Care Association, 2023).

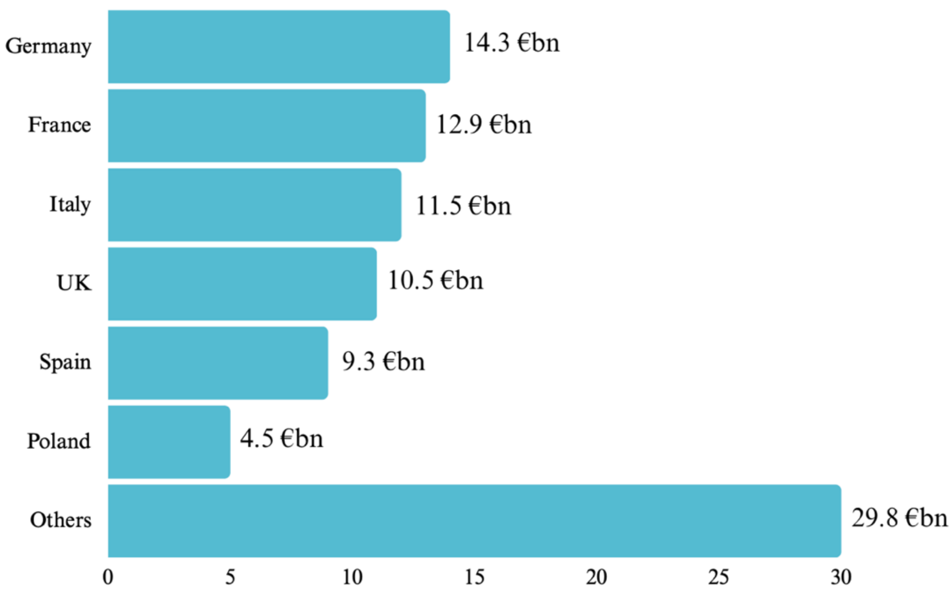


Figure 5: European market for cosmetics. Adapted from (The Personal Care Association, 2023).

Data from September 2024 confirms that L'Oréal remains the largest cosmetics company in the world. As of September 2024, the French giant has a market value of 225,1 € billion. It oversees well-known brands such as Maybelline, Garnier and Urban Decay. This represents an 11.81% decrease from its 289,55 € billion valuation at the end of 2023. Despite this decline, L'Oréal's market capitalization still accounts for more than half of the total value of the top 10 cosmetics companies as illustrated in Figure 6 (Oberlo, 2024). L'Oréal is followed by Givaudan, a Swiss multinational renowned for its expertise in fragrance creation. With a market capitalization of 45.6 € billion, Givaudan ranks second in the cosmetics sector. However, despite securing the second spot, its valuation is only about one-fifth of L'Oréal's, underscoring the French company's unparalleled dominance in the global beauty and personal care industry (Oberlo, 2024).

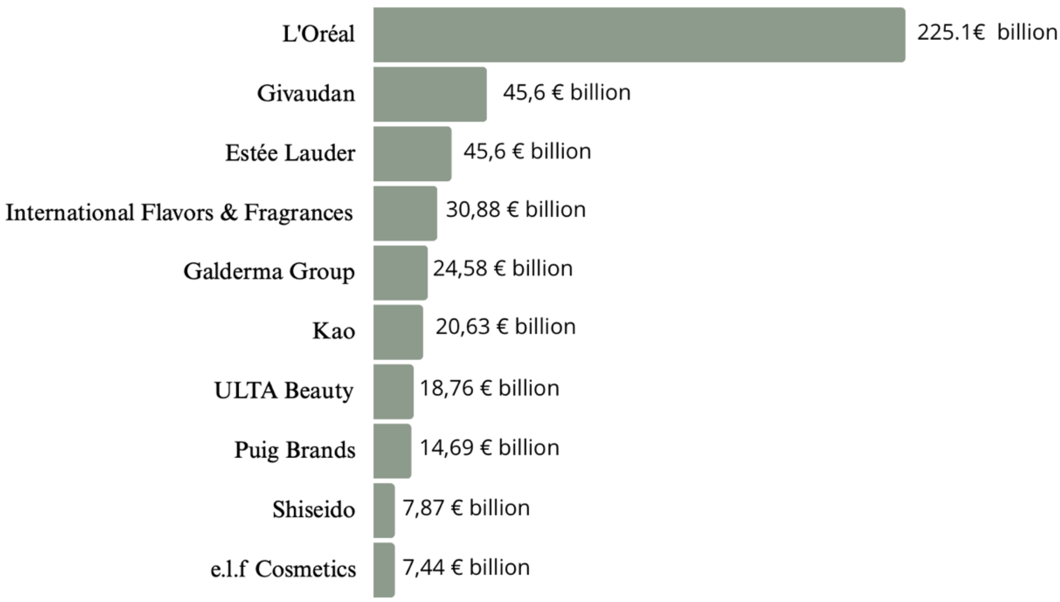


Figure 6: Largest Cosmetic companies (by Market Cap) , adapted from (Oberlo,2024).

The European cosmetics market is dominated by several key product categories. Skin care tops the list with a notable value of 25.6 € billion, while toiletries follow closely at 21.5 € billion. Hair care products rank third, generating 15.7 € billion in revenue. Fragrances and perfumes come next, contributing 14.0 € billion, and decorative cosmetics round out the top five categories with a total of 11.5 € billion (The Personal Care Association, 2023).

The cosmetic industry also plays a substantial role in job creation across Europe. It directly employs 259,244 people, while an additional 2,676,571 jobs are supported indirectly. Furthermore, induced economic effects contribute to over 587,000 additional

jobs, bringing the total employment impact to more than 3 million people. This data highlights the industry's extensive value chain, supporting millions of livelihoods and generating economic stability across various regions (The Personal Care Association, 2023).
Cosmetics and personal care products are recognized as essential to the well-being of individuals. According to recent studies, 72% of European consumers consider these products important or very important in their daily lives. Cosmetics are not merely superficial items; they fulfil fundamental roles such as personal hygiene, self-care, and protection of the skin and hair (The Personal Care Association, 2023).
Consumers use an average of over seven different cosmetic products daily, and nearly thirteen different products weekly (The Personal Care association, 2022). This frequent usage reflects the integral role cosmetics play in modern lifestyles. For many individuals, these products contribute significantly to their sense of self and confidence. In fact, 71% of consumers report that cosmetics and personal care products improve their quality of life, while 70% believe they are important or very important for building their self-esteem (The Personal Care association, 2022).

b) Cosmetics database:

Beyond the global market leaders and major players, the cosmetic industry is also characterized by the vast number of ingredients and products available. The cosmetic sector includes a staggering diversity of more than 20,000 registered ingredients, spanning both natural sources and synthetic materials (Lee et al., 2024). Among the most widely used are compounds like glycerine, hyaluronic acid, retinol, and ceramides (Lee et al., 2024). The effectiveness of a cosmetic product largely depends on the specific combination and concentration of its ingredients. Yet, given the enormous variability of ingredient blends and the confidentiality of many formulations, it becomes unfeasible to experimentally assess every possible interaction and outcome. As a result, alternative methods such as the use of artificial intelligence are being explored to better analyse product composition and assist in making personalized recommendations after diagnosing skin conditions (Lee et al., 2024).

As the global cosmetics industry becomes increasingly complex and competitive, with thousands of products and ingredients on the market, new technologies are being explored to better meet consumer expectations. Among emerging solutions, AI is proving particularly valuable enhancing innovation, tailoring products to individual needs, and streamlining processes throughout the production and marketing lifecycle. Before exploring its applications in more detail, it is essential to first understand the key principles and definitions of AI.

1.3. Artificial Intelligence

The field of Cosmetic is evolving rapidly, driven by technological progress and innovative approaches to patient care. AI is attracting growing interest for its ability to enhance various aspects of medical practice, including diagnosis, treatment planning, patient engagement, practice management, and even social media development (Haykal, Ascher, et al., 2024).

According to the European Parliament, AI is considered "the technology that defines the future" (Parlamento Europeu, 2020). In other words, AI consists of the ability of a machine to reproduce skills like those of humans, such as reasoning, planning and creativity. Thus, AI allows technical systems to perceive their surrounding environment and solve problems, acting with the aim of achieving a specific goal, and even being capable of adapting their behaviour (Kania et al., 2024).

Long considered futuristic, AI has become a practical tool, enhancing productivity, precision, and efficiency across industries, particularly in healthcare, pharmaceutical research, retail and e-commerce, education and security/defence (Li et al., 2022).

AI is now deeply embedded in many areas of modern life. Figure 7 was created using VOSviewer and data from Web of Science (2021-08-26), and it offers a visual representation of how different research topics related to AI are interconnected. It illustrates the breadth of AI's influence, from healthcare and energy to autonomous vehicles, robotics, and digital communication tools. In certain specialized applications, AI has even outperformed human capabilities, highlighting its growing significance across disciplines (Y. Jiang et al., 2022).

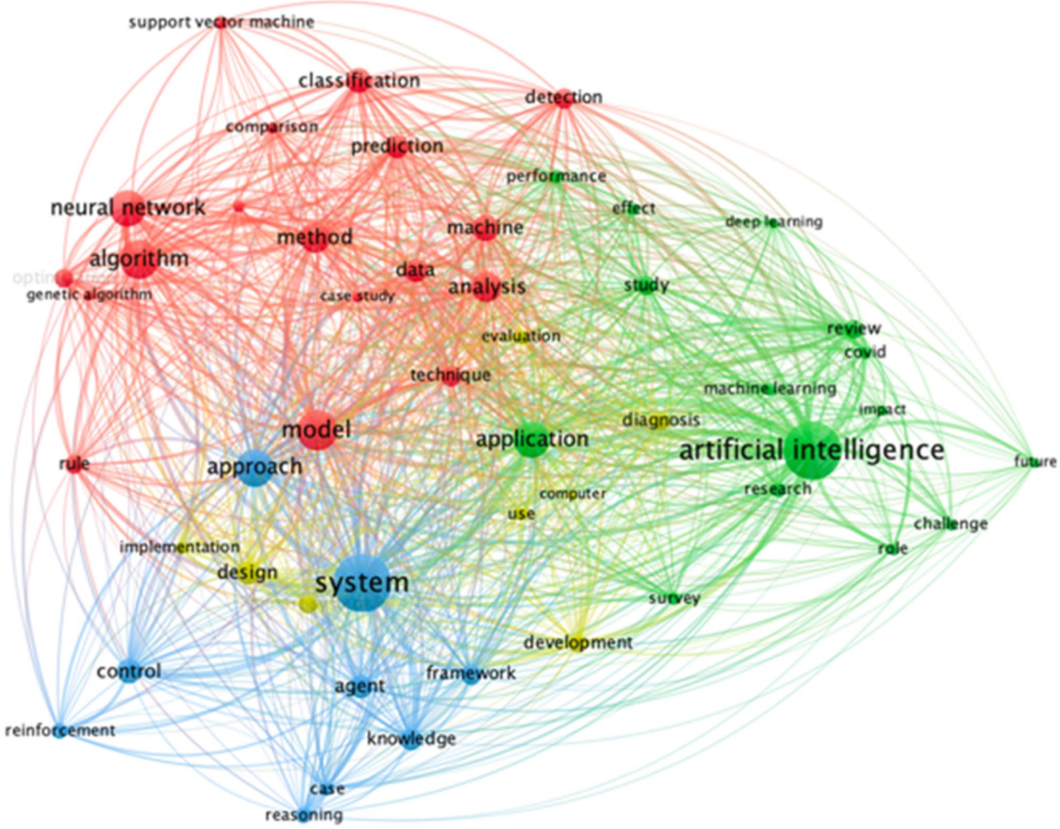


Figure 7: Semantic Network of Artificial Intelligence adapted from (Y. Jiang et al., 2022). This work is licensed under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License.

At its core, AI involves enabling machines to replicate human cognitive processes such as: reasoning, planning and creativity by processing information, interpreting sensory input, and autonomously making decisions to reach predefined objectives. More specifically, AI technologies operate by receiving data, either pre-prepared or collected through sensors like cameras, analysing this information and responding accordingly. The core process involves building algorithms that classify and analyse data, then make predictions. Through exposure to feedback and outcomes, the system refines its behaviour: a process known as machine learning. They can adapt their behaviours by learning from the effects of their previous actions, allowing for autonomous operation (Elder et al., 2021; Parlement européen, 2023; Vatiwutipong et al., 2023). This technology has found applications in various fields, including medicine, where it assists with repetitive tasks traditionally relying on human experts. In healthcare, AI is utilized for screening, diagnosis, treatment planning, and epidemiological analyses, augmenting the capabilities of medical professionals and improving efficiency in patient care (Elder et al., 2021; Parlement européen, 2023; Vatiwutipong et al., 2023).

To better understand how AI systems learn and make decisions, it is essential to explore two of its most influential components: Machine Learning and Deep learning, concepts which are illustrated in Figure 8 (Kania et al., 2024).

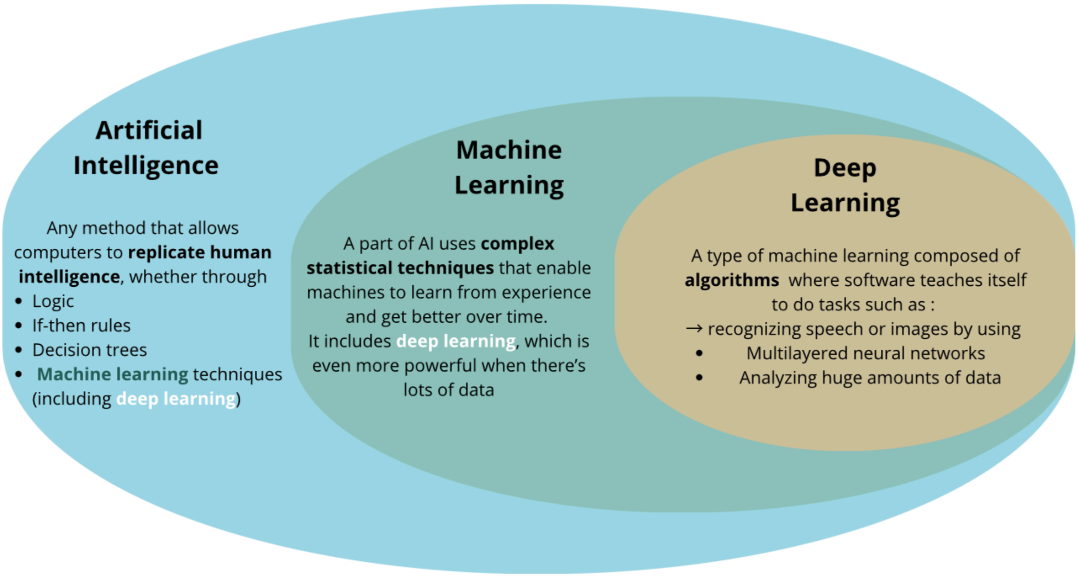


Figure 8: Overview of AI and its Subfields adapted from (Bini, 2018).

Machine learning (ML) is a subfield of AI that involves the development of algorithms and statistical models that enable machines to learn from data without being explicitly programmed. It involves computational techniques that learn from examples, instead of operating from predefined rules and natural language processing. These techniques regard the ability of a computer to transform human language and unstructured text, into machine readable structured data that reliably reflect the intent of the language. In essence, they emulate the cognitive processes of human learning, by using real data to inform decision-making (Sahni & Carrus, 2023; Vatiwutipong et al., 2023).

ML refers to the process by which artificial neural networks (ANNs) are trained. The network generates a prediction, which is then compared to a known correct answer provided by a labelled dataset. The discrepancy between the predicted and actual outcome allows the network to adjust its internal parameters. This training strategy is commonly used in applications involving pattern recognition (Elder et al., 2024).

Deep learning (DL) is a part of AI that uses layered neural networks to analyse data without needing human supervision. It breaks down information into different levels of complexity. For example, in image recognition, the first layer might identify simple features like edges and contrasts. The next layer could recognize shapes, and higher layers combine these information to understand what the image actually depicts. This approach allows DL systems to learn on their own and improve at tasks like recognizing images, processing language, and making decisions, like how humans understand information (Elder et al., 2021).

Figure 9 illustrates the structure of a **deep neural network**, highlighting how information flows through an input layer, multiple hidden layers, and finally an output layer. Each connection between nodes represents the transfer and transformation of data across the network (Y. Jiang et al., 2022).

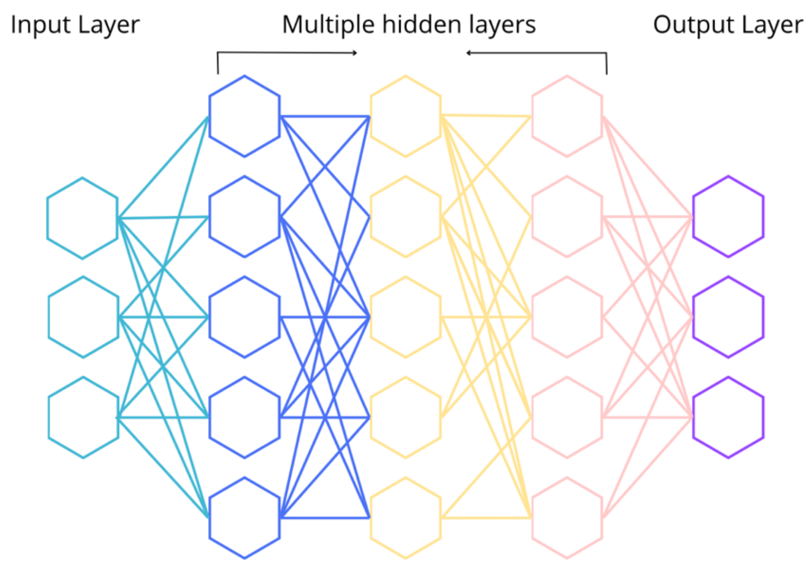


Figure 9: Deep Neural Network. Adapted from (Y. Jiang et al., 2022).

Although technology has advanced considerably over the years, emerging innovations like AI and ML are ushering in a new era for healthcare (Javaid et al., 2022). These tools make it possible to optimize even the smallest and most complex tasks with remarkable precision. While ML is already being used in medical settings, it holds even greater potential for future applications, such as the cosmetic industry (Javaid et al., 2022).

Within the cosmetic field, the literature identifies three main areas that are likely to undergo, or already face, significant changes in the upcoming years due to AI:

- **Ease diagnosis and predict treatment outcomes**: In clinical settings, AI-based systems such as three-dimensional (3D) facial mapping are being implemented to predict treatment outcomes and adapt interventions accordingly. These innovations already offer valuable support to healthcare professionals and require dermatologists to stay up to date to improve both patient care and workflow efficiency (Elder et al., 2024).
- **Optimize/fasten cosmetic product development:** AI and ML are particularly promising in this area, as product development studies involve complex challenges such as optimizing formulations, selecting appropriate ingredients, analysing structure-property relationships and evaluating performance (Mann et al., 2025). Traditional trial-and-error approaches are often inefficient and resource-intensive in addressing these demands. The integration of AI and ML methods offers new possibilities to streamline these processes (Mann et al., 2025; Xin et al., 2024). Within this field, the contribution of AI in ingredient innovation must be highlighted, as AI has the potential to accelerate the discovery and evaluation of new compounds. ML models can predict the efficacy of formulations, thus reducing the time and costs of traditional research and development (Eppler & Ma, 2025).
- **Tailored cosmetic product recommendation**: The incorporation of AI in this area is already a reality due to the existence of sophisticated at-home devices capable of assessing skin condition. Furthermore, some devices function through augmented reality (AR) technologies, enabling users to virtually test different products. This is particularly relevant in makeup products. These tools support individuals in making more informed choices regarding their skincare routines, but at the same tome, they can also be of great assistance to professionals, such as pharmacists, in forecasting tailored cosmetic products to each specific client (Grech et al., 2024). In the consumer experience domain, AI enhances engagement through features like virtual try-on tools, while data analytics help brands adapt to shifting market demands and behaviours. Altogether, these advances promote more customized, effective, and sustainable approaches in the development and delivery of cosmetic products (Eppler & Ma, 2025).

AI when combined with immersive technologies such as augmented reality, forms the foundation of a growing field known as **Beauty Tech** (Elder et al., 2024).

- **Beauty Tech**

Beauty tech refers to the growing integration of AI and AR in the cosmetic industry, particularly through the development of virtual try-on tools and diagnostic applications. These technologies represent a new frontier in personalized skincare and haircare by going beyond traditional questionnaire-based approaches. Instead of relying solely on user input, they incorporate facial imagery directly into the analysis process, enabling more tailored and interactive product recommendations (Elder et al., 2024).

Among the technologies developed within Beauty Tech, two stand out as illustrated in Figure 10:

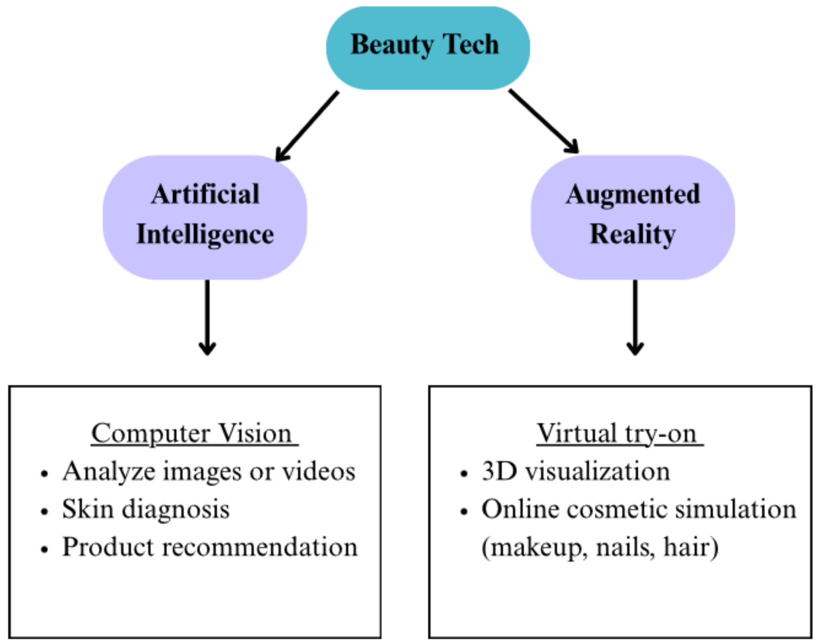
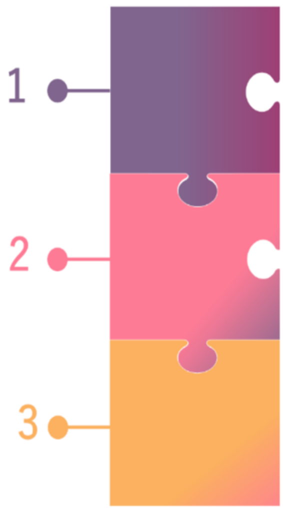


Figure 10: Key technologies behind beauty Tech adapted from (Gao et al., 2020; Grech et al., 2024).

- **Computer vision:** This refers to the ability of computers to replicate biological vision by analysing and interpreting images or videos. Its primary goal is to extract three-dimensional information from visual data through techniques such as image processing, pattern recognition and geometric modelling. The ultimate objective is to enable machines to understand visual content, similarly to human perception. With the advancement of machine learning, research in computer vision has increasingly shifted from traditional approaches to more sophisticated methods based on deep learning, particularly using CNNs (Gao et al., 2020).
- **Virtual try-on** based on **Augmented Reality**: AR blends real-world environments, captured through smartphones or computers, with superimposed virtual 3D elements (Micheletto et al., 2025). In cosmetics, this technology powers virtual try-on applications that allow users to preview the results of makeup, hair dye, or skincare products in real time. This functionality enhances transparency, improves consumer trust, and helps manage expectations by offering a realistic and interactive product experience (Grech et al., 2024).

Highlights



The skin is a multifunctional organ that protects the body, regulates temperature, and supports immune and sensory functions. Its composed by three layers: epidermis, dermis, and hypodermis that work together with skin appendages to maintain balance and enable cosmetic and therapeutic applications.

Cosmetics support hygiene, well-being, and self-confidence, while reflecting deep social and cultural significance. As a global industry, they shape lifestyles, influence beauty standards, and impact economies.

AI replicates human reasoning and learning by analysing data and adapting its responses. It enhances efficiency and precision across multiple fields of modern life.

2. Objectives

Skincare and cosmetic products have become an integral part of many people's daily routines, going far beyond aesthetics to address hydration, protection, and overall skin health. As previously reviewed, the cosmetics market has grown substantially in recent years, reflecting an increased awareness of skin-related issues and a strong demand for products that are both effective and personalized (Grech et al., 2024; Lee et al., 2024a). As consumers become more informed and selective, the need for high-performance, tailored skincare solutions has never been greater (Vatiwutipong et al., 2023).

However, the abundance of products and ingredients available can make it difficult for consumers to identify what suits their skin best. At the same time, pharmacists, often the first point of contact for patients seeking skincare advice, are expected to provide personalized recommendations, despite limited time and resources (Brzozowska & Gotlib, 2023). In this context, AI appears as a valuable solution. It enables more accurate skin assessments, supports decision-making through algorithm-based product matching, and enhances patient education with interactive and data-driven tools (Hash et al., 2025).

Based on this background, this work aims to explore how AI can unlock product counselling in cosmetic dermatology. It focuses on the contribution of AI to skin diagnostics, with tools that allow for more precise and personalized assessments (Kania et al., 2024). It also examines how AI can support tailored product recommendations, predict treatment duration and outcomes, and improve patient education through digital platforms (Bandaru B & Rambabu K, 2025). Particular attention will be given to the role of pharmacists, who may benefit from these technologies to enhance the quality and relevance of their advice. To provide a more tangible example of AI market relevance nowadays, a case study on L'Oréal will be addressed. Finally, the limitations and ethical concerns surrounding the use of these technologies such as data privacy, accessibility, and algorithmic bias will likewise be discussed (Abu Hammour et al., 2023; Hasan et al., 2024).

3. Methods

This study was based on a systematic literature review covering publications from 2018 to 2025, conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The search and data collection focused on systematic reviews, analyses, and meta-analyses retrieved from databases such as PubMed, Sciencesdirect, and Google Scholar, among others. The keywords used during the search included *Artificial Intelligence*, *Cosmetic Dermatology*, *Personalized Skin Care*, *Cosmetic Market*, and *Diagnosis*. In total, 67 records were collected from the databases, along with 10 web pages, and 3 legal decrees. The evaluation and inclusion of the records followed predefined inclusion and exclusion criteria are illustrated in Figure 11.

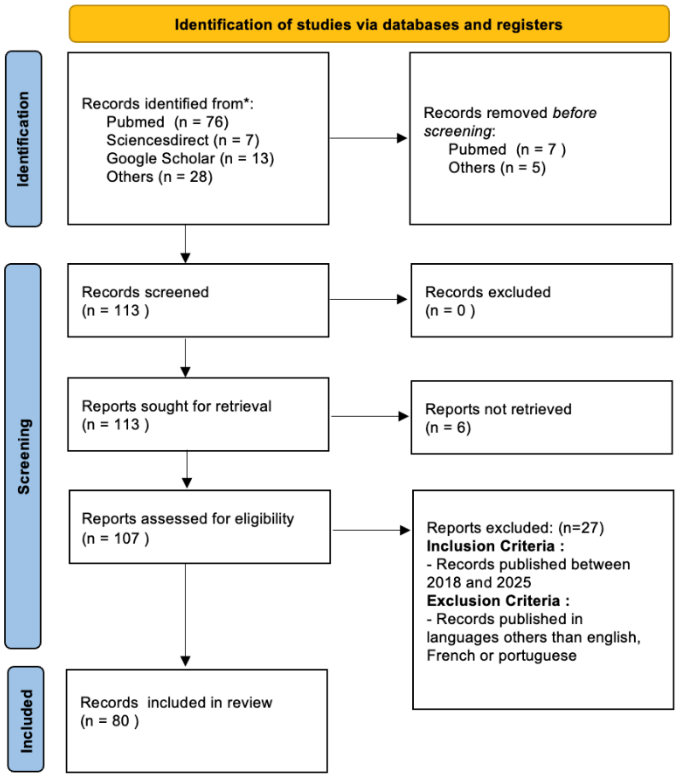


Figure 11: PRISMA 2020 flow diagram.

4. Skin diagnosis through AI

The integration of AI into cosmetology is revolutionizing the industry through innovations such as at-home skin analysis devices that assess skin quality and augmented reality apps that let users virtually test makeup products (Grech et al., 2024).

4.1. Skin assessment

In the field of cosmetic dermatology, accurate assessment of skin condition is essential to offer effective, personalized care. Traditionally, pharmacists relied on visual observation and manual tools to evaluate the skin. However, with the advent of AI, these assessments have become more precise, objective, and scalable. A range of key parameters can now be measured using AI-driven technologies, including hydration, sebum production, pigmentation, skin thickness and barrier function (Vatiwutipong et al., 2023).

Hydratation:

Skin hydration is a key indicator of skin health and plays a critical role in cosmetic evaluation and treatment recommendations (Kania et al., 2024). Water is a major component of the skin and contributes significantly to its physiological balance. It supports essential functions such as acting as a barrier against external aggressors (e.g., water, chemicals, allergens) and maintaining the skin's biomechanical properties. Additionally, inadequate hydration has been associated with a higher risk of pressure injuries, delayed wound healing, and chronic skin conditions (Bernatchez & Bichel, 2023). AI now enables objective and automated analysis of skin hydration, particularly through advanced imaging techniques (Kania et al., 2024).

Traditionally, skin hydration was primarily assessed using methods such as clinical observation, corneometry, electrical conductance, as well as transepidermal water loss (TEWL) measurements (Bernatchez & Bichel, 2023).

The following AI tools are nowadays available to access the skin hydration status.

- **Capacitive imaging** is a non-invasive method that estimates skin hydration by measuring the **electrical conductivity** of the skin's surface as illustrated in Figure 12. Since water increases conductivity, this technique provides an indirect but reliable measurement of the skin's moisture level (Chirikhina et al., 2021).

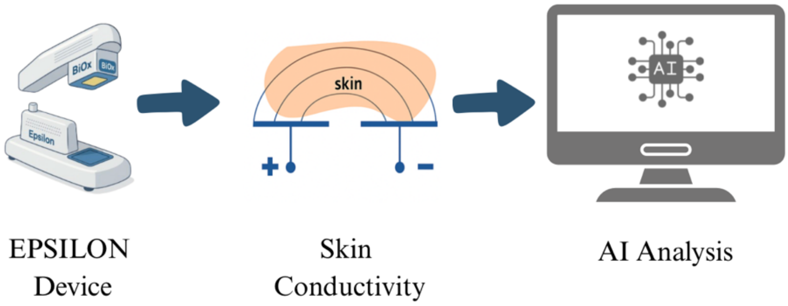


Figure 12: Skin Conductivity measurement and AI interpretation adapted from (Chirikhina et al., 2021).

In a study conducted by (Chirikhina et al., 2021), capacitive images were taken from various facial and body regions such as the **cheeks, forehead, chin, and neck**. These regions were selected due to their varying skin textures and hydration characteristics.

The images collected were then analysed using AI algorithms. Several deep learning models were tested, and the **DenseNet201** CNNs achieved the highest classification accuracy in predicting hydration levels based on image features (Chirikhina et al., 2021).

Table 2 presents the mean and standard deviation of Epsilon values, which reflect the skin water content across different facial areas. The results show that the lips and nose have the lowest hydration levels, while the cheek, eye corner, and under-eye regions are the most hydrated. Additionally, hydration is more consistent on the lips and nose (lower standard deviation), whereas the neck and eye area show greater variability. This highlights how hydration naturally varies across the face, which is important for personalised skin assessment (Chirikhina et al., 2021).

Table 2: Average Epsilon Values Measured Across Different Facial Skin Sites, adapted from (Chirikhina et al., 2021).

Skin Site	Measurements (n)	Mean Epsilon (AU)	Standard Deviation
Lips	86	21.42	5.75
Nose	116	23.13	4.65
Forehead	232	24.05	6.4
Chin	157	25.28	6.99
Neck	108	26.15	8.19
Cheek	239	26.46	7.36
Eye Corner	92	27.32	7.89
Under-eye	144	28.0	7.93

The capacitive images capture subtle changes in skin surface properties that are not always visible to the human eye. AI models learn to detect and interpret these patterns, offering consistent and reproducible assessments across individuals (Kania et al., 2024).

Sebum production:

Sebum production is a crucial parameter in evaluating skin condition, particularly for patients seeking cosmetic treatments targeting issues such as acne (Kania et al., 2024). Traditionally measured by visual observation or absorbent materials like lipid-sensitive tapes and bentonite clay, these methods lack objectivity and consistency (Liu et al., 2023). In response to this limitation, some studies were aimed to compare several AI models including: Support Vector Machines, VGG-16, and ResNetfor, all used to classify pre-processed skin images according to their corresponding sebum levels (Borade et al., 2022). The study showed that among the tested AI models, ResNet achieved the best performance, correctly classifying skin images according to sebum levels with an accuracy of 98%. This result confirms that deep learning models, especially ResNet, can offer a more objective and reliable evaluation of sebum assessment condition than traditional, manual methods (Borade et al., 2022; Kania et al., 2024).

In a related study, Kothari et al. (2024) developed a method to classify facial skin into four types: normal, dry, oily and combination. They applied a face detection technique based on the Multi-Task Cascaded Convolutional Neural Network (MTCNN), which segmented each image into four facial regions: the forehead, left cheek, right cheek, and nose (Vatiwutipong et al., 2023). A CNNs was then trained to evaluate the oiliness level of each region and assign a corresponding skin type (Kania et al., 2024; Vatiwutipong et al., 2023). The model predicted the oiliness level of each facial region (forehead, cheeks, nose) individually. These predictions were then aggregated into a global percentage of oiliness, used to assign an overall skin type. The system reached 92% accuracy, though results showed a slight bias toward oily classifications, likely due to the dataset's imbalance (Kothari et al., 2021).

Pigmentation:

Pigmentation disorders such as freckles and age spots are frequent concerns in cosmetic dermatology. A macroscopic examination is often the initial approach to skin assessment (Holcomb, 2021). For an effective treatment, it is essential to detect and classify these lesions accurately. CNNs trained on large datasets have proven to be highly effective when performing this task. One study successfully used AI to classify over 12,000 facial images by pigmentation type, achieving an accuracy comparable to expert dermatologists. These findings confirm the value of AI as a reliable and efficient tool to support diagnosis and improve treatment planning for pigmentation issues (Kania et al., 2024).

Complementing these advances, Canfield's VISIA AI skin analysis system integrates cross-polarization and ultraviolet illumination to assess both surface and subsurface chromophore concentrations. This technology enables the precise detection of brown and red pigments such as those found in spider veins, port-wine stains, and hyperpigmentation, offering dermatologists enhanced visualization to guide treatment selection and monitor progress more objectively (Holcomb, 2021).

Skin thickness and collagen density

Skin thickness is a key parameter in cosmetic dermatology, particularly for selecting appropriate treatments (Kania et al., 2024). However, as referred in the introduction of the present thesis, it varies significantly with anatomical location, age, sex, and ethnicity, making its assessment both important and challenging (Vatiwutipong et al., 2023b).

Measuring skin thickness is clinically relevant for two main reasons (Borade et al., 2022).

- **Treatment planning**:

  The depth of skin layers influences the penetration of topical products and the effectiveness of dermatological or cosmetic treatments (e.g. peels, lasers, fillers).

  → *Thinner skin may require milder or adapted interventions* (Borade et al., 2022).

- **Skin condition evaluation**:

  Unusual thickness values can indicate skin damage or pathology (e.g. inflammation, collagen loss, atrophy).

  → *These measurements support early diagnosis and personalised care* (Borade et al., 2022).

Traditionally, thickness assessment involved invasive skin biopsies followed by microscopic analysis methods that are both time-consuming and invasive (Kania et al., 2024; Vatiwutipong et al., 2023). To address these limitations, a non-invasive alternative have emerged:

- **High-resolution ultrasound imaging**: This technique enables a precise visualization of the main skin layers: stratum corneum, epidermis and dermis, by generating cross-sectional images of the skin, as illustrated in Figure 13. Afterwards the generated images are processed with differents AI tools, such as Neural Networks and Random Forest: a machine learning algorithm that builds multiple decision trees and combines their outputs to improve prediction accuracy and reduce the risk of overfitting (Chirikhina et al., 2021).

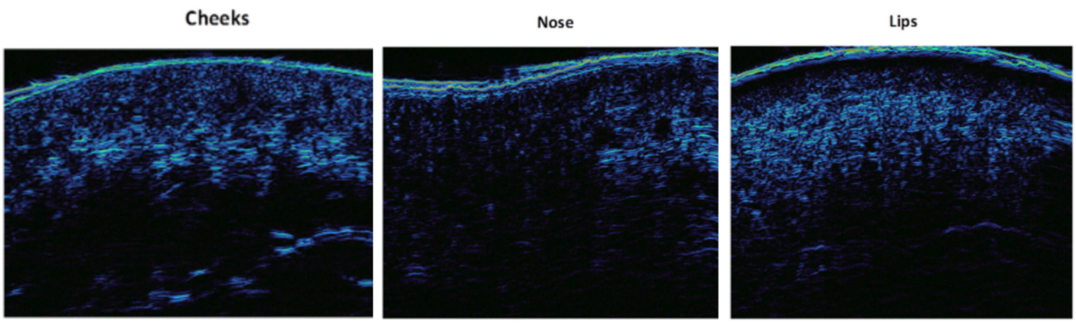


Figure 13: Representative High-Resolution Ultrasound Images of Various Skin Siteses adapted with consent from (Chirikhina et al., 2021).

To better understand the variability of skin thickness across facial regions, Table 3 provides the measured values for the stratum corneum, epidermis, and dermis layers at eight anatomical sites. The comparisons were made by identifying the minimum and maximum values for each layer. Results showed that the cheek had the highest dermis proportion (95.3%), while the neck had the lowest (92.0%). The stratum corneum was thickest on the chin (0.038 mm) and thinnest on the arm (0.024 mm). Regarding the epidermis, it ranged from 0.047 mm on the arm to 0.083 mm on the chin. These variations reflect structural differences between facial regions. In addition, higher standard deviations, such as those found for the cheek and chin may indicate greater variability in skin condition and a potentially higher risk of damage (Chirikhina et al., 2021).

Table 3: Skin Layer Thickness in Different Facial and Body Areas, adapted from (Chirikhina et al., 2021).

Skin Site	Measurements (n)	Full Skin Thickness (mm)	Standard Deviation	Stratum Corneum (mm)	Epidermis (mm)	Dermis (mm)	Dermis (%)
Arm	498	1.306	0.194	0.024	0.047	1.185	90.7%
Eyelid	453	1.309	0.226	0.025	0.052	1.238	94.5%
Neck	490	1.378	0.187	0.026	0.054	1.267	92.0%
Lips	477	1.426	0.294	0.027	0.064	1.32	92.5%
Forehead	451	1.647	0.173	0.028	0.065	1.569	95.2%
Cheek	551	1.69	0.437	0.032	0.074	1.611	95.3%
Nose	487	1.912	0.316	0.033	0.077	1.821	95.2%
Chin	339	1.929	0.271	0.038	0.083	1.837	95.2%

Table 4 provides a summary of the four skin assessment tools previously discussed.

Table 4: Summary Table of AI-Based Methods for Skin Assessment adapted from (Kania et al., 2024).

Skin Parameter	Traditional Method	AI-Based Method
Sebum production	Manual visual assessment	Classification of skin images using SVM, VGG-16, ResNet, CNN with MTCNN detection
Skin hydration	Visual assessment or subjective grading	Contact capacitive imaging, ultrasound, MRI + DL algorithms (e.g. DenseNet201)
Skin thickness	Skin biopsy and microscopic analysis	High resolution imaging + Neural network or Random Forest
Pigmentation disorders	Visual classification by dermatologist	VISIA® system with UV/polarized light + CNN classification of 12,000+ images

Understanding key skin characteristics like hydration, thickness, and whether the skin is oily or dry is important for designing effective cosmetic treatments to each specific patient. The studies reviewed in this section show that non-invasive imaging methods, such as contact capacitive imaging or high-resolution ultrasound can accurately measure skin moisture and thickness. These techniques, combined with DL algorithms, enable skin classification more precisely (Kania et al., 2024).

Now that we have explored several exemples of targeted skin assessments using AI, we will turn our attention to more comprehensive AI systems. These advanced technologies can evaluate multiple skin parameters simultaneously, thus offering a detailed and comprehensive diagnosis of an individual's skin condition.

4.2. Imaging and analysis technologies

Recent breakthroughs in AI particularly in ML, DL and computer vision are revolutionizing the field of dermatological diagnostics. These technologies are now increasingly applied to skincare, as they enable the analysis of an individual skin profile thus supporting real-time adjustments to skincare routines (Hash et al., 2025; Pranitha et al., 2025).

In skincare, AI facilitates eases diagnosis by training algorithms to detect specific skin conditions such as acne, rosacea, or alopecia from photographic inputs. Leveraging DL, these systems can identify subtle visual features and deliver rapid, automated assessments, particularly through mobile-based platforms (Pranitha et al., 2025).

Tools like Haut.AI apply these techniques to user-submitted images, combining clinical data and personal input to recommend customized skincare routine (Hash et al., 2025).

Working Process:

The process typically involves the upload of high-resolution facial images, which are then processed to identify clinical and aesthetic skin features. The system uses CNNs, VGGNet, or DenseNet, which allow for the detection of conditions such as dryness, oiliness, pigmentation, wrinkles, and redness, achieving impressive accuracy levels of over 97% in some cases. These algorithms ensure a precise and objective understanding of the user's skin condition (Thi et al., 2025).

In more advanced settings, high-definition imaging tools such as contact capacitive imaging, ultrasound, and multispectral scan are used to measure skin hydration, oil levels, barrier function, and elasticity (Vatiwutipong et al., 2023).These devices capture detailed biophysical parameters across different facial zones (e.g., T-zone, cheeks, chin), contributing to a multi-dimensional dermatological profile (Vatiwutipong et al., 2023).

We will now examine through Table 5 two types of computer vision applications in skincare: One designed for professionals using dedicated imaging devices, and another intended for consumers through mobile applications.

Table 5: Key differences between medical and at-home skin assessment technologies.

	Professional Tools	**Home-Based Applications**
Examples	VISIA, Quantificare, Antera 3D, FotoFinder	Skin360, AI Skincare, Aysa, SkinConsultAI
Equipment	HD cameras, 3D sensors, UV/polarized lighting	Smartphone or tablet with front camera
Analysis Quality	Very high clinical precision	Moderate accuracy, dependent on lighting and device quality
Parameters Measured	Wrinkles, pores, spots, sebum, redness, texture, vascularization, volume	Spots, shine, redness, texture, superficial wrinkles
Target Users	Dermatologists, aesthetic practitioners	General consumers, public
Usage Environment	Medical or aesthetic clinic	At home, through a mobile app
Main Functions	Clinical diagnosis, treatment planning, follow-up	Personalized cosmetic recommendations
Type of Algorithm	Advanced deep learning, image segmentation	Embedded machine learning, simplified image recognition
Result Interpretation	By a trained healthcare professional	Automatically provided by the app
Main Objectives	Clinical improvement	Beauty orientation, customized skincare routines

4.2.1. Professional Tools using Computer Vision

To illustrate the growing integration of AI into professional skin analysis, the next section summarizes the main computer vision systems currently used in aesthetic clinics. Most of these technologies are designed for skincare and cosmetic purposes, helping to assess skin quality, track signs of aging, or recommend personalized treatments. However, one notable exception is FotoFinder, a device that, beyond its aesthetic applications, is also widely used in dermatology for the detection and analysis of skin cancers, highlighting the potential of AI to support both preventive and clinical care.
Recent improvements in imaging technologies have led to the development of specialized devices designed to evaluate facial skin conditions with greater accuracy. These systems are now widely used in aesthetic dermatology clinics. By capturing various types of skin-related data, they can have combined them with those of the patient, therefore training the ML models and consequently enhance the precision of skin assessments (Thunga et al., 2024).

a) Canfield

Canfield offers a comprehensive portfolio of high-performance skin imaging systems including the Vectra H2, IntelliStudio, Visia Skin Analysis, Vectra WB360, Vectra XT, and Reveal Imager. These systems integrate the following technologies:

- RBX® - Enables the distinction of red and brown skin chromophores;
- Grayscale - Enhances contour visualization;
- Probe tracking skin surface changes over time, without requiring physical markers.

Altogether, these technologies generate realistic 3D simulations and colour maps that model volume changes such as filler outcomes, while also measuring key parameters like wrinkles, texture, pores and spots (Elder et al., 2021).

In Figure 14 the VISIA Skin Analysis System is portrayed. This system is widely used in dermatology clinics and the skincare industry, it evaluates eight essential skin features:

- Wrinkles;
- UV damage;
- General and brown spots;
- Pores;
- Redness;
- Texture;
- Porphyrins: bacterial metabolites that fluoresce under UV light and are often linked to acne-prone skin.

By using cross-polarized and ultraviolet lighting, the Visia system captures both surface and subsurface conditions and estimates photoaging with TruSkin Age, a module that compares a patient's skin to age-based normative datasets (Wang et al., 2018).

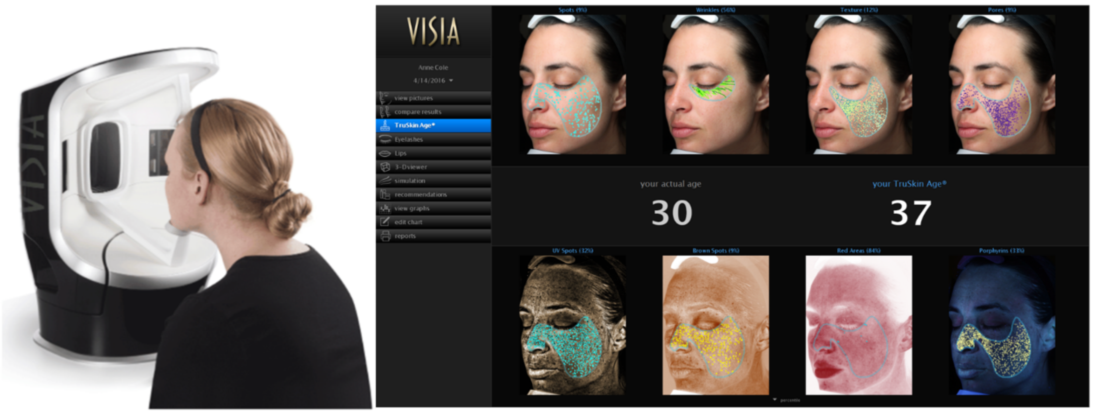


Figure 14: The VISIA skin analysis system. Image courtesy of Canfield Scientific, Inc., granted in June 2025.

This system is especially effective in laser treatment planning, as it highlights underlying melanin and vascular structures, making it possible to adjust laser settings more precisely in cases such as hyperpigmentation, port wine stains, or spider veins (Kania et al., 2024). Despite its technical sophistication and enhanced image quality, current clinical literature offers limited evidence that this software significantly outperforms traditional diagnostic method. Furthermore, cost constraints may hinder an equitable access to this software (Elder et al., 2021). Nevertheless, patient feedback remains overwhelmingly positive: in one evaluation, 86% of users reported improved understanding of their skin concerns, 100% would recommend the system, and 62% preferred clinics equipped with VISIA over those without it (Wang et al., 2018). However, the system's bulk and image capture time may limit ease of use; it requires patient data input and is composed of a 31-pound imaging chamber (13 × 14.2 × 20.9 inches) connected to specialized software (Cook et al., 2022).

b) Quantificare

Quantificare has developed a range of 3D imaging systems, including the LifeViz Mini Face, LifeViz Micro, Infinity Face, Body & Breast, and LifeViz Mini Pro, designed for precise visualization and evaluation of skin and facial structures. These portable and high-resolution tools capture the face or body from multiple angles, enabling the detailed assessment of skin features such as wrinkle depth, pore size, oiliness, vascular structures, and pigmentation (Elder et al., 2021).

Among them, the LifeViz Micro has been validated for clinical use, especially in studies involving atrophic acne scars, anti-aging protocols, and dermal fillers. It uses dual-beam light pointers to ensure reproducible imaging and can be employed as a standalone 3D camera or integrated into advanced analysis software (Petit et al., 2018). The LifeViz Mini Pro, the most recent model, incorporates AI-assisted image sorting and real-time Wi-Fi transfer, offering 3D reconstructions of facial morphology with high geometric accuracy. It also allows procedure simulations such as filler injections, helping practitioners visualize treatment outcomes and enhance digital consultations (Petit et al., 2018).

c) Miravex

The Antera 3D® device, developed by Miravex, is a high-precision skin imaging system that generates detailed 3D representations of the skin surface by analysing light reflection and shadow. Using a patented reconstruction algorithm, the device aligns the captured data with a virtual 3D facial model to assess a wide range of skin parameters, including wrinkles, texture, haemoglobin concentration, pigmentation, redness, pores, and volume. These capabilities make it a valuable tool for monitoring inflammatory activity such as changes in skin distribution with greater precision (Anqi et al., 2022; Elder et al., 2021).

Several clinical studies have employed the Antera 3D® to evaluate conditions such as acne scarring or photokeratitis, highlighting its utility in both cosmetic and dermatological applications (Anqi et al., 2022). The workflow of this device is shown in Figure 15, courtesy of the company.

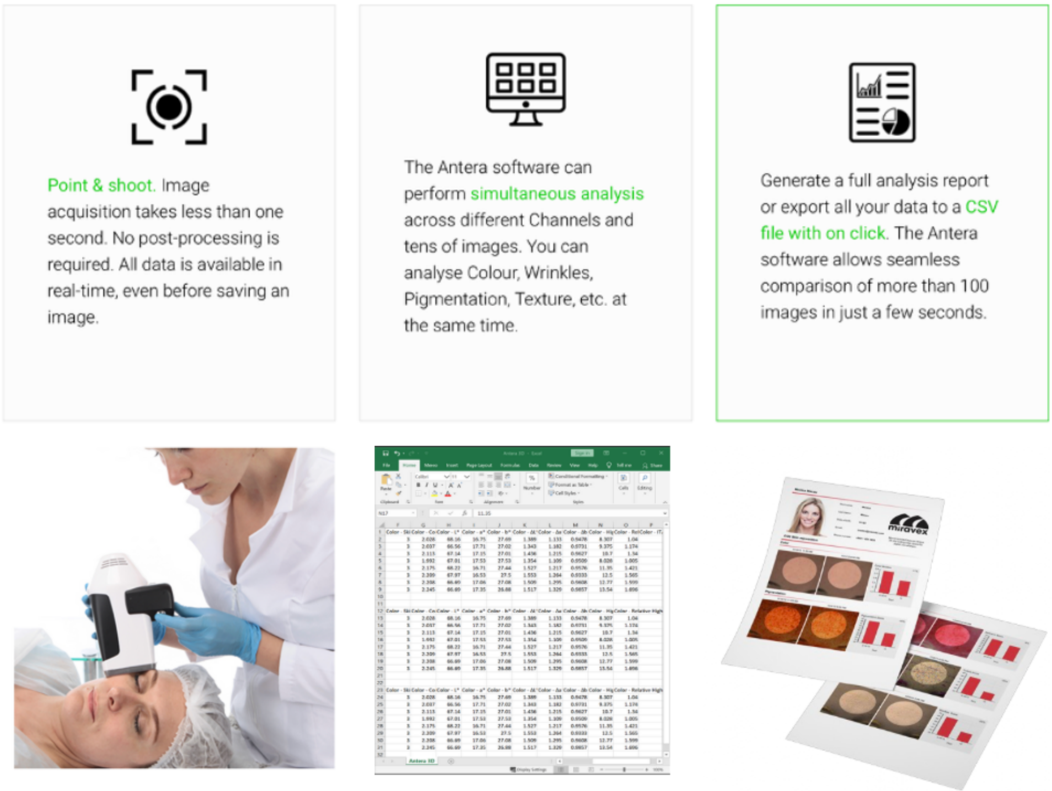
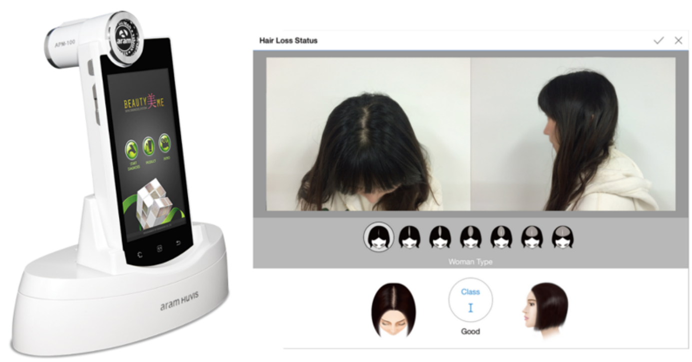


Figure 15: Antera 3D® device, The image was reproduced with written consent from Miravex Limited, Inc , granted in June 2025.

d) Aram Huvis

Aram Huvis developed the AI-Scalp Grader, a device that analyses the scalp using high-magnification images (60×) captured by a trichoscope, a device used for the magnified, non-invasive examination of the scalp and hair to diagnose hair disorders, as illustrated in Figure 16. It uses the Scalp Photographic Index to classify scalp types and score five conditions: dryness, oiliness, redness, folliculitis, and dandruff. In clinical trials, personalized treatments based on the device's evaluation helped improve scalp health. However, its broader clinical impact is still being studied. Because it focuses on specific features, its performance may vary across hair types and skin tones, and more diversetesting is recommended (Elder et al., 2024).

While in-office technologies offer thorough skin assessments and impactful visual demonstrations, their use often requires substantial financial investment and a steady flow of patient interest, which may limit their practicality in standard dermatology settings. Furthermore, these devices tend to be expensive, large, and not readily available to patients unless used within the framework of a clinical study (Elder et al., 2024).



Scalp type by scalp symptoms (10 types)

	Sort	Fine dead skin cells	Excess sebum	Erythema between hair follicles	Erythema of the hair follicles	Pustule	Dandruff	Hair loss
A	Good(Normal)	X	X	X	X	X	X	X
B	Dry	O	X	X	X	X	X	X
C	Oily	X	O	X	X	X	X	X
D	Sensitive	X	X	O	X	X	X	X
E	Atopic	O	X	O	X	X	OX	X
F	Seborrheic	OX	O	O	X	X	OX	X
G	Trouble	OX	OX	X	O		OX	X
H	Dry dandruff	O	X	X	X	X	O	X
I	Oily dandruff	X	O	X	X	X	O	X
J	Hair loss	X	X	X	X	X	X	O

Figure 16: Aram Havis Scalp Grader System, Image courtesy of ArumHavis, Inc , granted in June 2025.

e) FotoFinder

FotoFinder technology is widely used across various dermatological fields, including skin cancer detection, trichoscopy for hair analysis, aesthetic assessments, clinical dermatology, and dermatological research, reflecting its diagnostic versatility. The company offers several tools for skin analysis, such as the ATBM Master, which performs full-body scans and automatically detects lesions. FotoFinder also provides handheld devices for high-resolution facial imaging. These systems can assess skin texture, pigmentation, and track changes over time. The ATBM Master includes automated scoring for psoriasis using PASI (Psoriasis Area and Severity Index) metrics, which evaluate the severity and spread of lesions based on redness, thickness, scaling, and body surface area (Sabour, 2021).

FotoFinder has also developed the Moleanalyzer pro, an AI-based system for skin lesion analysis. It was tested in clinical studies like *"Man Against Machine"*, where a DL model for melanoma detection performed similarly to a group of 58 dermatologists. This tool uses a version of Google's Inception v4 model trained on dermatological images and was validated using large international databases. Additionally, FotoFinder's Trichoscale DX is used for hair and scalp analysis. While AI brings valuable insights, some experts warn about relying too heavily on automated tools for clinical decisions (Elder et al., 2021; Sabour, 2021).

Table 6 provides a consolidated summary of the various computer vision systems described earlier, highlighting their main features and applications.

Table 6: Computer vision systems adapted from (Elder, 2021).

Company	Software Features	Facial Measurements	AI Applications
Canfield	RBX imaging, grayscale analysis, tracking without markers	Detection of wrinkles, spots, pore size, texture, redness	3D simulation and pre-treatment visualization
Quantificare	3D facial mapping, wrinkle and pore analysis, skin tone and vascular mapping	Facial metrics including angles, dimensions, and proportions	Automated photo classification and face data management
Miravex	3D surface modelling using light and shadow interpretation	Assessment of wrinkles, texture, pore visibility, skin volume	Monitoring and analysing aesthetic skin treatments
FotoFinder	Automated high-res lesion detection, PASI scoring, scalp and hair imaging	Skin lesion identification, scalp and hair condition evaluation	Digital documentation and interpretation of dermatological findings
Aram Huvis	Hair and scalp condition analysis using image-based assessment	Evaluation of scalp health and condition	Scalp health scoring based on photographic inputs

4.2.2. Public available Tools

While professional computer vision systems offer highly precise skin diagnostics in clinical settings, recent technological advancements have brought similar capabilities to consumer-oriented applications. These at-home mobile solutions, powered by AI, enable users to assess their skin condition quickly and conveniently using only a smartphone or tablet. In the following paragraphs some examples of these public available solutions will be briefed (Kania et al., 2024).

a) AI Skincare: Perfect Corporation

Perfect Corporation has developed a series of AI-powered skin analysis tools for iOS devices, aiming to deliver rapid and accessible facial diagnostics outside clinical settings. All versions of the application are based on a shared machine learning algorithm trained on a dataset of more than 70,000 facial images, representing a wide range of ages and ethnic backgrounds, to ensure a robust and inclusive performance (Cook et al., 2022).

In a clinical study conducted with 50 participants with various skin types and ages, the AI Skincare application was used on an iPad Pro (12.9-inch, 5th generation, 2021) running iOS 15.5. The tablet was mounted at face level, and users were seated on a height-adjustable stool. Participants removed glasses and face coverings, and were instructed to maintain a neutral facial expression, while front-facing the camera (with no flash). The application required no manual data input and completed the full skin analysis in less than 10 seconds. The evaluation focused on five primary parameters: spots, wrinkles, redness, texture, and pores. A raw score was calculated for each, with lower scores indicating more pronounced skin concerns (Cook et al., 2022).

The system demonstrated performance comparable to established diagnostic tools, particularly showing increased sensitivity in detecting and quantifying wrinkles. Beyond the five core parameters, the software can evaluate 14 total skin features, including acne, dark circles, under-eye puffiness, hydration, oiliness, firmness, skin radiance, and upper and lower eyelid drooping (Cook et al., 2022).

b) The Aysa application

The Aysa application, developed by VisualDx, is an AI-powered mobile tool designed for skin symptom analysis. It combines targeted clinical search capabilities with a comprehensive database of over 120,000 dermatological images, covering 200 distinct skin conditions across all Fitzpatrick skin types. Leveraging expert medical insights and advanced ML techniques, the app provides personalized skin assessments (Marri et al., 2024).
Aysa operates directly on the user's device, utilizing platforms such as Apple's CoreML on iOS to optimize ML processes locally. It also adapts its outputs by incorporating the user's medical background, enhancing the relevance of its suggestions. The app is available to the public and can be downloaded on both iOS and Android platforms (Marri et al., 2024).

c) Neutrogena's Skin360 application

Neutrogena's Skin360 application, available for both iOS and Android platforms, allows users to perform at-home skin evaluations using their smartphone camera. The app analyses various skin features such as dark spots, under-eye circles, wrinkles, texture irregularities, and fine lines. Based on these assessments, it generates a personalized Skin360 score and offers tailored skincare product recommendations (Elder et al., 2021).

Beyond the initial evaluation, the app also supports longitudinal monitoring: users can track changes and improvements over time daily, weekly, or monthly by performing repeated skin scans. Additionally, Skin360 incorporates lifestyle tracking tools that monitor variables known to affect skin health, including sleep patterns, physical activity, stress levels, and daily product usage, thereby offering a more comprehensive overview of skin-related behaviours (Elder et al., 2021).

d) Opté Precision Skincare System: AI-Powered Beauty Wand

Although image-based analysis has enabled personalized skin assessments through uploaded photographs, the emergence of handheld scanning devices has further advanced individualized skincare technology. One such innovation is the Opté Precision Skincare

System, developed by Procter & Gamble for home use. This device functions as a beauty wand equipped with an LED light to enhance contrast with melanin, a high-speed digital camera capturing up to 150 images per second, and an applicator tip containing a targeted serum and concealing formula. As the device glides over the skin, it detects hyperpigmentation at the pixel level and applies product only where needed. The serum not only provides immediate coverage for areas such as lentigines and dark spots but also delivers active ingredients such as niacinamide and SPF, to help gradually improve pigmentation over time (Elder et al., 2021).

4.2.3. Localization and Detection of Skin Characteristics

In cosmetic dermatology, it is not always enough to determine whether a skin condition is present, identifying its location is equally important. This is particularly relevant for conditions such as acne, wrinkles, vitiligo, or pigment spots, which often occur in multiple isolated areas. Precise lesion localization is essential for assessing severity, tracking treatment progress, and applying targeted skincare (Vatiwutipong et al., 2023).

To achieve this, AI uses two main approaches:

- **Image segmentation**, which analyses each pixel of an image to classify it as part of a lesion or not.
- **Object detection**, which identifies distinct regions (bounding boxes) containing a condition and may also classify their type (e.g., acne, wrinkle).

In several studies, segmentation models like U-Net and Deeplab-v3+ have been successfully used to detect the exact areas where wrinkles or spots appear. These models work by turning the image into a probability map, where each pixel gets a score showing if it belongs to a skin problem. This creates a "map" of the skin that shows the shape and position of each issue very precisely (Vatiwutipong et al., 2023).

Other researchers use models like YOLO (You Only Look Once) or Faster-RCNN, which can both find the location of a lesion and tell what type it is. These systems are fast and can analyse a full-face photo, like a selfie, in one step. This makes them ideal for use in mobile apps. For example, some models can detect acne areas on the face and then send this information to a smart LED device, which adjusts its treatment settings automatically (Vatiwutipong et al., 2023).

4.2.4. Severity Estimation

Beyond detecting a skin condition, evaluating its severity is important for choosing the right cosmetic treatment. AI can help do this automatically, either by giving a score (regression) or by classifying the severity into levels like mild, moderate, or severe (Kania et al., 2024).

Many researchers have explored the use of selfie images for automatic severity grading. However, results can be affected by lighting, facial expressions, and skin tone. To improve this, Jiang et al. adapted a CNN to give severity scores for wrinkles, pores, and folds using images from people aged 18–80 with various ethnicities and lighting conditions. While not always matching dermatologist ratings exactly, the model showed reasonable consistency (Vatiwutipong et al., 2023).

Later, Flament et al. tested similar models on over 500,000 selfies from European and Chinese women and found a strong correlation between AI results and expert evaluations for five conditions: forehead wrinkles, periorbital wrinkles, nasolabial folds, lower face sagging, and redness (Flament et al., 2023).

Other studies used high-quality professional images. For example, Seck et al. analysed 3D skin texture to assess wrinkles and pores. Wang et al. developed a model called Acne-RegNet, which classified acne severity with 94% accuracy, outperforming other AI models. However, front cameras reduced performance slightly (Vatiwutipong et al., 2023).

Overall, deep learning models, especially CNNs, are widely used to estimate skin condition severity. These models are trained on labelled image datasets and compared to expert assessments. While more validation is still needed in some cases, AI shows great potential to support dermatologists and improve cosmetic diagnosis (Vatiwutipong et al., 2023).

4.3. Cosmetics Counselling in Pharmacies: Roles and challenges

Community pharmacists today play an increasingly important role in maintaining and promoting skin health. In addition to their traditional responsibilities, they now frequently provide guidance on cosmetic and dermo cosmetic products: From recommending appropriate sunscreens to advising on over-the-counter treatments for common concerns such as acne (Alotaibi et al., 2024). Thanks to their accessibility and daily contact with the public, pharmacists are often the first healthcare professionals approached for skin-related advice. Their position enables them to offer personalized support, combining preventive strategies with early intervention when needed. This evolving role highlights the need for pharmacists to be well-informed about skin physiology and disorders, so they can offer safe, effective, and tailored recommendations to their patients (Almaghaslah, 2022; Alshahrani et al., 2021).

A recent study conducted in the Asir region of Saudi Arabia demonstrated that skincare products represent a significant portion of non-medicinal items sold in pharmacies, with a reported rate of 19% of all such products (Almaghaslah, 2022).

Another survey carried out in the western region of Saudi Arabia reinforced this perspective. In this study, almost 90% of pharmacists stated they provide direct and in-person counselling related to cosmetic products, viewing it as a core part of their professional role. In addition, over 85% of them routinely asked clients about allergies or skin sensitivities before recommending any product, demonstrating a proactive and patient-centered approach to safety (Alshahrani et al., 2021).

Given the pharmacist’s key role in advising and guiding patients in the selection and use of cosmetic products, it is relevant to explore how artificial intelligence could support and enhance this practice. As new technologies emerge, AI tools may offer valuable opportunities to improve the precision, personalization, and efficiency of cosmetic counselling in pharmacies.

4.4. Artificial Intelligence in Pharmacy: Enhancing Skin Analysis and Counselling

Due to their accessibility and growing expertise in digital health tools, pharmacists are emerging as important contributors to the management of skin conditions (Gustafson et al., 2024).

Thanks to AI and ML algorithms, pharmacists can now process and interpret large volumes of clinical data, including electronic health records, laboratory results, and medication histories. This supports the identification of drug-drug interactions, enhances medication safety, and facilitates more precise therapeutic recommendations tailored to the individual needs of each patient (Chalasani et al., 2023).

AI is also reshaping communication and engagement in pharmacy. Intelligent systems such as virtual assistants can respond to common patient queries and generate personalized guidance regarding treatment plans or cosmetic recommendations. This contributes to a more continuous and accessible model of care, especially in community settings where pharmacists often serve as the first point of contact for health concerns (Gustafson et al., 2024).

Moreover, the rise of AI in health academia exemplified by tools like ChatGPT illustrates the profession's openness to innovation. These technologies are already being explored for their potential in patient education and decision support, indicating a paradigm shift in both pharmacy practice and education (Abu Hammour et al., 2023).

While AI is unlikely to replace pharmacists, it offers them an opportunity to elevate their role as healthcare providers. As healthcare systems become more complex and data-intensive, AI is positioned to serve as a collaborative partner, supporting pharmacists in offering safer, more personalized, and evidence-based services (Davenport & Kalakota, 2019). This evolution also applies to the field of cosmetic counselling, where AI-powered remote consultations can assist pharmacists in assessing skin type, recommending suitable cosmetic products, and educating patients about preventive skincare—thus reinforcing their role in health promotion and individualized care (Brzozowska & Gotlib, 2023).

Enhancing Pharmacy Practice Through AI: A Real-Life Example

a) Boots:

A concrete example of how AI is being integrated into pharmacy practice can be seen through the recent initiative launched by Boots a leading pharmacy and health & beauty retailer in the UK. The company has introduced an AI-powered digital tool designed to support pharmacists in offering personalized skincare advice. Rather than functioning as a diagnostic device, the tool assists pharmacists by analysing patient responses and visual information to recommend suitable over-the-counter skincare products. This initiative is complemented by a comprehensive dermatology training program offered to over 4,400 Boots pharmacists, aiming to strengthen their knowledge of common skin conditions such as eczema, acne, and psoriasis. By combining professional training with AI-based support systems, pharmacists are empowered to provide more confident and tailored skincare consultations directly in community pharmacy settings, enhancing the overall quality (Smith S, 2025).

b) Thea Care: An AI implanted in Pharmacy

Other AI implementation example in community pharmacy regards the AI-powered skin diagnostic solution developed by TheaCare. This in-store system is designed to support pharmacists in providing personalized dermo cosmetic advice. By using a tablet as an interface, customers can take a selfie in the pharmacy. The AI algorithm, developed in collaboration with dermatologists, analyses the image to detect as the skin´s dryness, redness, uneven tone, as well as pore visibility. Then, it generates immediate product recommendations tailored to the individual's skin needs (Thea Care GmbH, 2025).

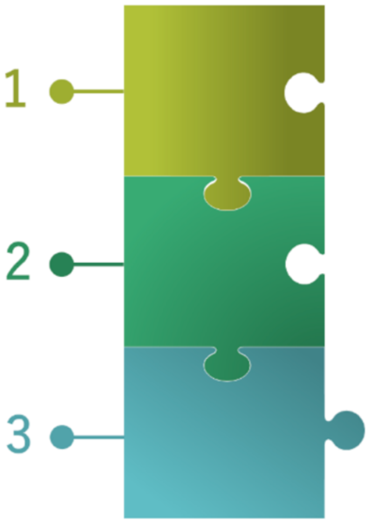
Figure 17 illustrates the use of AI-powered skin diagnosis technology in a pharmacy setting, highlighting how pharmacists can leverage digital tools to provide more accurate and personalized skincare recommendations to patients (Thea Care GmbH, 2025).

Figure 17: Personalized Skin Analysis in Community Pharmacies, adapted with Chatgpt from TheaCare.

From a business perspective, this innovation increases customer satisfaction and product sales, by offering a modern, personalized experience aligned with the consumer expectations (Thea Care GmbH, 2025).

Beyond assessment, the pharmacist's role extends to guiding patients toward appropriate skincare routines and product choices. With the growing access to diagnostic tools, including AI-powered technologies, pharmacists are now better equipped to deliver informed and individualized advice. This evolution naturally culminates in the ability to recommend products that are precisely tailored to everyone's skin profile and concerns.

Highlights



AI enables fast, objective, and reproducible evaluation of skin parameters like hydration, pigmentation, and sebum, using non-invasive methods such as capacitive imaging and ultrasounds.

In clinical and consumer settings, tools like VISIA® or smartphone apps (e.g. AI Skincare, Skin360) offer high-resolution imaging and personalized skin analysis, making diagnostics more accessible.

In pharmacies, AI assists pharmacists in analysing patient data or facial images, supporting personalized skincare advice and strengthening their role in evidence-based cosmetic counsellin

5. Cosmetic recommendations through AI

5.1. The Need for personalized skincare

Selecting an appropriate skincare product has become increasingly complex due to the overwhelming number of available formulations. With ingredient combinations ranging from natural to synthetic and estimated 20,000 differents ingredients and over 200,000 product combinations, consumers often struggle to make informed decisions (Grech et al., 2024).

This difficulty has been further intensified since the COVID-19 pandemic, which prompted greater consumer awareness and caution regarding health and product composition. Clients are now more inclined to examine the ingredient lists and assess the presence of irritants or allergens before purchasing, favouring transparency and scientific credibility (Grech et al., 2024). AI offers a solution to these challenges by decoding the complex relationship between skin biology and product composition. It also enables a dynamic and personalized model of skincare, replacing static recommendations with routines that adapt to the evolving needs of the user (Hash et al., 2025). Moreover, several free online databases such as EWG's Skin Deep® and the EU's CosIng allow consumers (and health professionals) to check ingredient safety, regulatory status, and potential hazards before purchase, complementing AI-supported counselling with transparent, evidence-based information on cosmetic formulations (EWG's Skin Deep, 2025).

Ultimately, the convergence of health-conscious consumer behaviour and technological innovation is accelerating the demand for personalized skincare. AI serves as a critical bridge in this context, helping users navigate the saturated market and select products aligned with their unique needs and goals (Grech et al., 2024; Hash et al., 2025).

5.2. Personalized recommendations

As previously discussed in the first section, AI systems begin by conducting a comprehensive skin diagnosis. This diagnostic phase provides the essential baseline from which personalized skincare recommendations are generated. The skin analysis is not a stand-alone process; it serves as the critical foundation for matching the user's specific needs with the most appropriate cosmetic solutions (Vatiwutipong et al., 2023). Before recommending products, the system collects information across several dimensions. Figure 18 presents the conceptual framework developed by (Bandaru B & Rambabu K, 2025). This conceptual framework used throughout this section, outlines the main components and processes involved in AI-driven personalized skincare product recommendation.

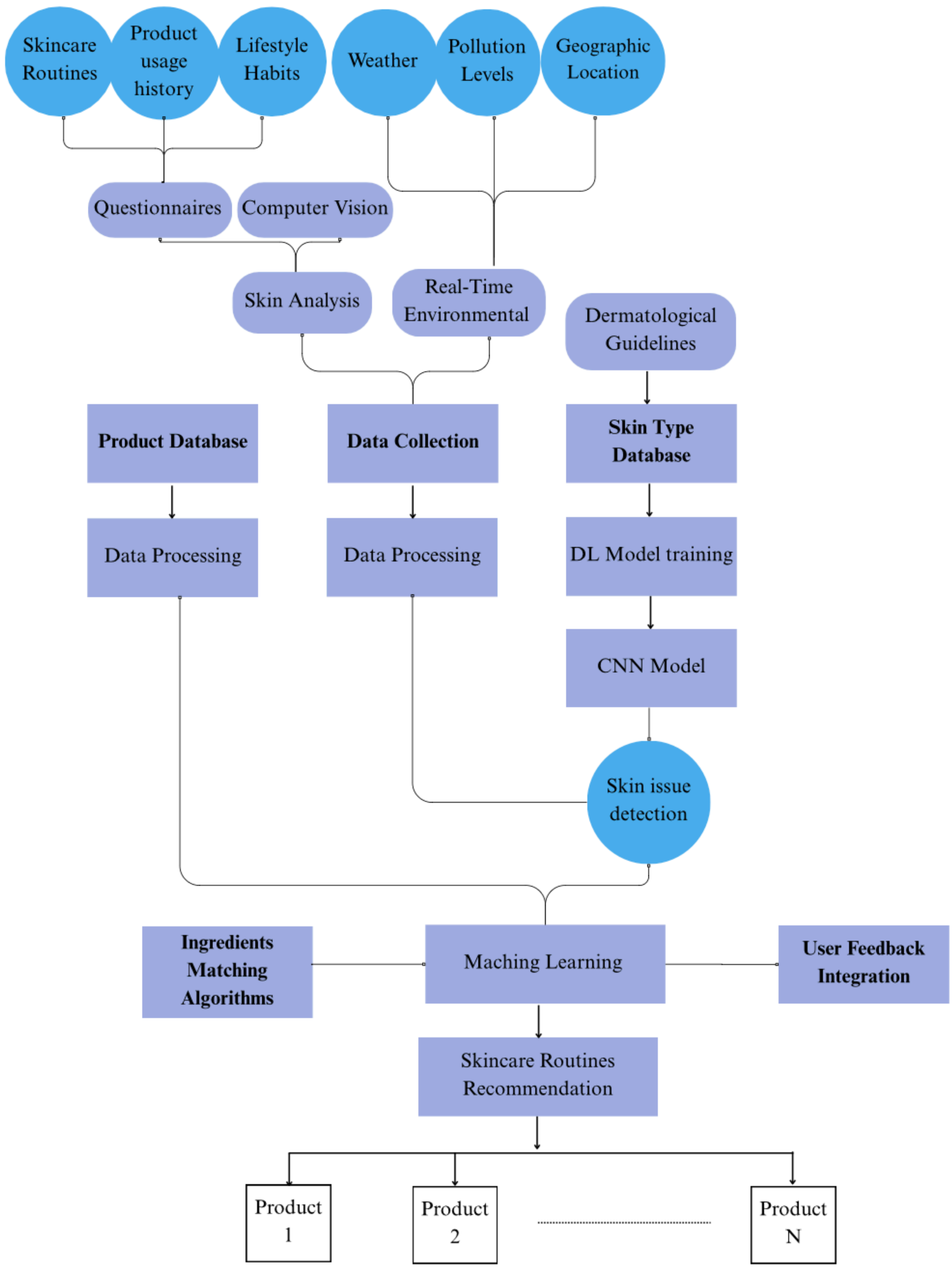


Figure 18: Implementation workflow adapted from (Bandaru B & Rambabu K, 2025).

5.2.1. Data Collection

a) Physiological data

Understanding a person's skin condition is the first step in offering targeted skincare suggestions. These systems collect essential dermatological information such as skin type, concerns such as dryness or sensitivity and hydration status, but also common skin problems: acne, pigmentation, aging, among others. Furthermore, additional attributes such as oil levels, skin tone, pore visibility, and sensitivity are likewise assessed to get a comprehensive skin profile (Bandaru B & Rambabu K, 2025; Thi et al., 2025). In certain cases, non-invasive imaging devices or probes, such as corneometers or ultrasound scanners are likewise used to measure hydration and skin structure on specific facial areas, thus enhancing the precision of the skin assessment (Kania et al., 2024).

b) Behavioural and self-reported data

To complement the physiological data, users are typically asked to complete questionnaires that explore their skincare routines, product usage history, lifestyle habits such as hydration, diet or sleep, as well as treatment expectations. These self-reported inputs include information about past reactions, texture preferences, and aesthetic goals (Bandaru B & Rambabu K, 2025; Vatiwutipong et al., 2023). The collection process often captures details about allergies and sensitivities to prevent adverse reactions. Over time, systems may also gather user feedback regarding product satisfaction, which helps refine future recommendations based on actual experience (Thi et al., 2025).

AI and digital diagnostic tools are transforming skincare personalization. Moving beyond simple image analysis, emerging AI technologies can now identify emotional indicators through subtle facial expressions, variations in skin tone, and thermal imaging, offering a more adaptive and emotionally responsive approach to skincare (HAYKAL et al., 2025).

c) Environmental data

External conditions also pose a significant impact on skin health. That is why skincare systems increasingly incorporate data related to a user's environment, such as air quality, humidity, UV exposure, and seasonal changes. This allows recommendations to be dynamically adapted, based on weather patterns or geographical location. For example, a routine designed for winter in a dry climate may differ significantly from one tailored to a humid summer environment (Vatiwutipong et al., 2023).

Example of Proven Skincare Beauty:

PROVEN Beauty, a California-based company, exemplifies the application of ML in personalized skincare by leveraging the Skin Genome Project, an extensive database comprising over 8 million consumer reviews, 100,000 skincare products, 20,000 ingredients, and more than 4,000 scientific and peer-reviewed publications (Elder et al., 2024). As mentionned in Figure 19, to initiate the personalization process, users complete a dermatologist-designed, AI-assisted questionnaire that gathers detailed information on their age, skin type, medical history, current skincare treatments, specific concerns (such as dryness, fine lines, or redness), ethnic background, and lifestyle habits, including stress, hydration, sleep patterns, diet, and geographic environment (Elder et al., 2024; Hash et al., 2025). This comprehensive dataset enables the platform to generate highly tailored skincare regimens, which are continuously adjusted based on user feedback and evolving skin conditions. By dynamically responding to factors such as hormonal fluctuations or seasonal variations, PROVEN ensures that its recommendations remain effective and relevant over time, supporting both immediate needs and long-term skin health (Hash et al., 2025; Proven, 2025).

Figure 19: A Three-step process for personalized skincare routines, adapted from (Proven, 2025).

Based on these inputs, the platform generates a personalized regimen including a cleanser, a day cream with SPF, and a night cream selected from 527 possible product combinations. For example, someone concerned with occasional breakouts and fine lines, who drinks three to four glasses of water per day, reports moderate stress, and lives in a high-UV, hard-water region, will receive a formulation containing over 50 targeted ingredients. These may include pre- and probiotics, salicylic acid, L-mantellic acid for acne, antioxidants like ginseng and green tea for environmental protection, sodium hyaluronate for hydration, and retinoic acid to address the aging signs (Grech et al., 2024).

5.2.2. Generation of personalized recommendations

Once the user's profile is established, AI-powered systems go beyond isolated product suggestions by proposing a structured skincare routine tailored to the individual's skin needs. The system will offer users a complete skincare routine, combining multiple products (e.g., cleanser, moisturizer, sunscreen) tailored to their needs. The recommendation will prioritize products that work well together in a complete regimen. (Bandaru B & Rambabu K, 2025).

In building these routines, AI systems draw from extensive ingredient databases to assess product compatibility. The system leveraged both consumer behaviour data and product ingredient databases to recommend products based on the compatibility between ingredients and users' skin concerns. This allows the algorithm to avoid recommending combinations that might cause irritation, such as exfoliating acids with retinoids especially for sensitive skin types. Similarly, systems consider ingredient interactions to maximize benefits, such as pairing hyaluronic acid with niacinamide to support hydration and the skin´s barrier function (Bandaru B & Rambabu K, 2025; Thi et al., 2025).

In addition to generating a regimen, modern AI tools offer clear justifications for each recommendation. These explanations help users understand why a certain product was selected, often highlighting the function of its core ingredients. Jones and Patel note that "the system aimed to match products with users based on ingredient compatibility, focusing on factors like skin sensitivity and common allergies" (Bandaru B & Rambabu K, 2025). The use of expert-backed knowledge allows the system to align suggestions with the best dermatological practices. For example, "the system integrates expert dermatological knowledge about common ingredients (e.g., retinol, salicylic acid, hyaluronic acid) and their effects on specific skin conditions" (Thi et al., 2025). Some tools also indicate which ingredients should be avoided, especially in the presence of sensitivities or allergies, thus improving safety (Thi et al., 2025).

Finally, these recommendations are often supported by educational elements such as visual explanations or predictive simulations. Certain platforms use scatter plot visualizations or AR tools to display the relationship between products and skin outcomes, helping users understand potential benefits and long-term results. As reported in "a visual forecast of the anticipated results using a combination of product function labels, user images, and efficacy ratings" is also used to enhance clarity and transparency (Grech et al., 2024).

5.2.3. Ingredient analysis through AI

AI enhances personalized skincare by analysing the chemical composition of cosmetic products and matching them with individual skin profiles. Algorithms can identify active compounds such as retinoids, AHAs, parabens, and sulphates and assess their compatibility with user-specific factors like skin sensitivity, allergies, or conditions such as rosacea or eczema. For example, benzoyl peroxide might be flagged as unsuitable for sensitive skin, while niacinamide could be suggested for oily or hyperpigmented skin. These tools outperform manual analysis by leveraging vast ingredient databases and dermatological research to deliver clinically relevant recommendations (Hash et al., 2025).

Beyond ingredient matching, AI also predicts structural and functional properties of cosmetic components like surfactants and preservatives, optimizing formulation stability and effectiveness. This reduces trial-and-error in product development and helps align skincare routines with user needs (Hash et al., 2025).

AI systems also contribute to safety by identifying potential irritants or allergens. One *in silico* model developed by Kalicińska et al. analysed molecular structures to predict sensitization risks avoiding animal testing while offering accurate safety profiling. In personalized skincare, similar tools could generate ingredient "avoid lists" tailored to individual sensitivities, helping prevent reactions such as itching or inflammation (Kalicińska et al., 2023).

Applications like ingredient scanners or diagnostic platforms go further by evaluating how active components address specific issues acne, aging, pigmentation, or sensitivity. One system developed by Lee et al. and depicted in Figure 20 combined facial scan data with product analysis to generate custom skincare recommendations using products already on the market. For example, hyaluronic acid may be suggested to boost hydration, or niacinamide to target pigmentation (Lee et al., 2024).

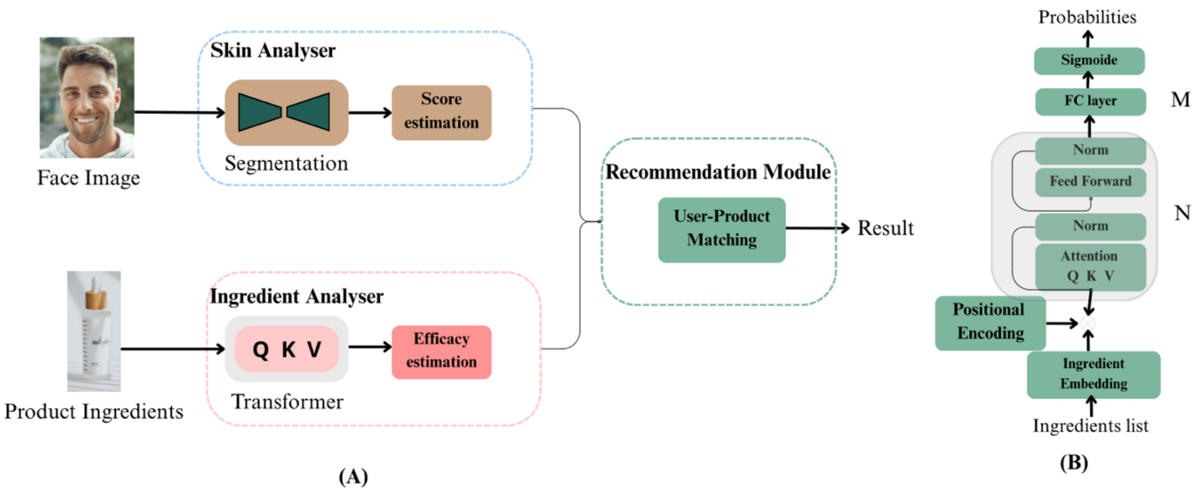


Figure 20: The structure of the recommendation system (A) and ingredient analyzer (B). (A) includes a skin analyser, an ingredient analyser, and a recommendation module. (B) illustrates the ingredient analyser model architecture , adapted from (Lee et al., 2024).

Some tools also assess sunscreen formulations from a photo of the packaging. A recently developed app identifies key features such as SPF, UV coverage, water resistance, form (cream, spray, etc.), and filters (zinc oxide, avobenzone) using on-device text recognition. Future versions could detect allergens from ingredient lists, further personalizing sunscreen choices (Elder et al., 2024).

Conventional methods for choosing skincare products, such as seeking advice from beauty consultants or using algorithm-driven digital tools, frequently fall short in accurately meeting the unique dermatological requirements of individuals. Advances in AI, especially in the fields of image recognition and pattern detection, now provide a promising foundation for creating smart, data-centric solutions tailored to personalized skincare (Thi et al., 2025).

In summary, AI-based recommendation systems deliver not only product suggestions but complete, rationalized skincare routines. They explain ingredient choices, advise on what to avoid, and guide users through a structured, safe, and personalized beauty regimen.

5.2.4. Follow-up and Adjustment Over Time

A defining strength of AI-based skincare recommendation systems lies in their ability to evolve. Rather than providing static advice, these systems adapt continuously to changes in skin condition, user preferences, and environmental factors. This adaptive capacity is made possible by integrating user feedback and contextual data into an iterative learning process (Bandaru B & Rambabu K, 2025).

Users can report their experiences with recommended products whether positive or negative by submitting ratings, comments, or updates on their skin condition. The algorithm is designed to continuously learn from user feedback, interactions, and product performance in order to refine the relevance of future recommendations. This feedback loop not only increases personalization over time but also contributes to greater user satisfaction by avoiding repeated mismatches (Bandaru B & Rambabu K, 2025).

This ability to anticipate change, rather than simply respond to it, brings AI recommendations closer to what might be expected from a professional dermatological follow-up. Over time, the system becomes a kind of digital skincare companion, capable of adjusting routines in response to both long-term trends (e.g., aging, hormonal shifts) and short-term fluctuations (e.g., travel, stress, environmental exposure). The literature suggests that future systems may even incorporate real-time monitoring for continuous assessment, pointing to the possibility of fully automated, evolving skincare plans (Thi et al., 2025).

Ultimately, this long-term, data-driven approach positions AI not just as a diagnostic or recommendation tool, but as a dynamic partner in the user's skincare journey.

5.3. Prediction of treatment efficacy

AI enhances patient satisfaction by better aligning expectations with achievable results (Grech et al., 2024). Advancements in AI are transforming the cosmetic industry by supporting personalized treatment decisions and enhancing patient experiences as presented in Figure 21 (Grech et al., 2024). By offering a concrete visualization of likely results, this technology empowers individuals to make more informed choices about aesthetic treatments. Being able to estimate treatment efficacy in advance allows both practitioners and clients to develop achievable and satisfying care plans. Unlike medical interventions driven by necessity, cosmetic procedures are elective and often shaped by personal preferences and budget. In this context, accurate forecasting helps professionals align treatment proposals with what users realistically hope to achieve, thereby fostering greater trust and satisfaction in the overall experience (Grech et al., 2024; Vatiwutipong et al., 2023).

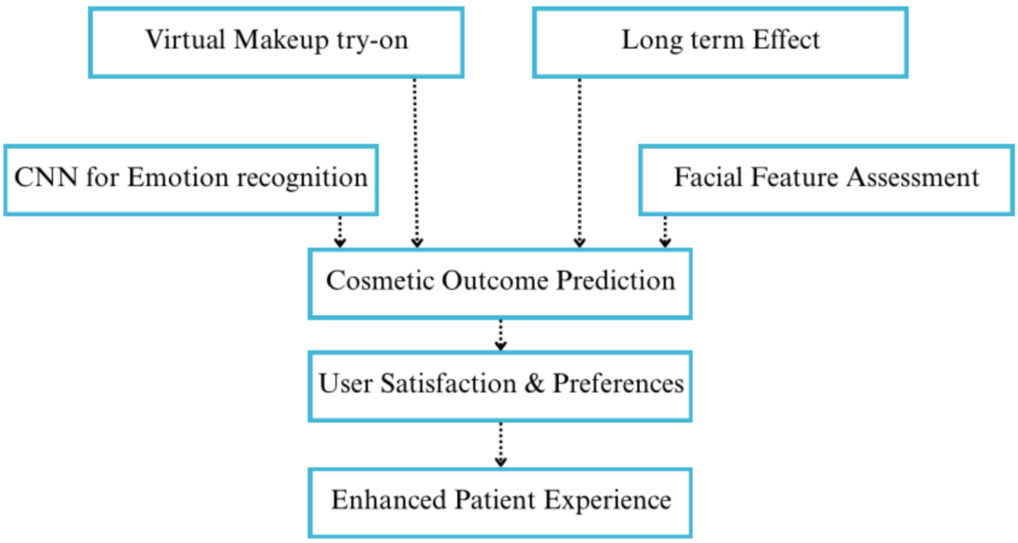


Figure 21: Cosmetic Outcome prediction using AI in cosmetology, adapted from (Grech et al., 2024).

In the field of skincare, an AI-based application known as *SkincareMirror* was designed to predict how a user's skin might evolve with continued use of specific cosmetic products. By combining information such as product functions, user-submitted images, and recorded efficacy data, the system generates a visual projection of the expected outcomes. This tool has proven particularly valuable for users with limited skincare knowledge, as it enables them to better anticipate results and make quicker, more confident choices. Its usefulness has been especially noted among male users, who typically engage less with traditional skincare consultations, with reported increases in both satisfaction and decision-making efficiency compared to conventional product selection methods (Vatiwutipong et al., 2023).

Customer satisfaction is essential in the cosmetic industry, as it directly impacts purchasing behaviour. Recent research has explored how AI can analyse emotional responses to improve personalized product recommendations. One study used CNNs to interpret EEG signals recorded while participants applied creams with different textures. These signals, categorized as “like” or “dislike,” were analysed across various frequency bands and processed into spatial-frequency matrices. The models achieved 75.4% accuracy in predicting user satisfaction. This pioneering approach offers valuable insight into consumer preferences and opens new possibilities for using physiological data to guide product selection. Future work could expand this method to include other sensory factors, such as fragrance, for an even deeper understanding of user experience (Haykal, Garibyan, et al., 2024).

Beyond visual tools, AI also leverages ingredient analysis to predict treatment outcomes. DL models trained on cosmetic formulations and user skin profiles can estimate the likelihood of efficacy for various concerns such as acne, dryness, or pigmentation, without requiring real-world product application. This approach supports safer, more targeted recommendations and reduces the risk of adverse reactions (Grech et al., 2024).

As these technologies evolve, they promise to offer even more sophisticated tools for simulating procedures and predicting personalized outcomes. AI thus transforms cosmetic care into a forward-looking, evidence-based practice that improves confidence, effectiveness, and satisfaction in both skincare and aesthetic treatments.

5.4. AI and Education

Artificial intelligence plays a growing role in educating both patients and professionals in the field of cosmetic dermatology as illustrated in Figure 22. It enhances understanding, promotes engagement, and supports more informed decision-making for skincare routines and treatment options (Kania et al., 2024).

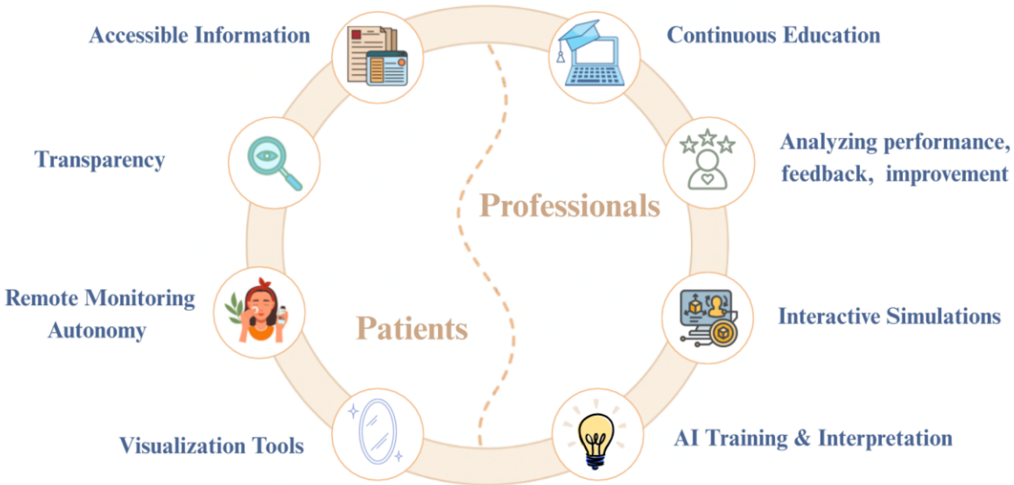


Figure 22: Education of Patients and Professionales through AI , adapted from(Dave & Patel, 2023; Haykal, 2025).

5.4.1. AI as an Educational Tool for Patients

AI empowers patients by making **health information more accessible, understandable, and actionable**. Through interactive platforms and mobile applications, patients can receive explanations about their health conditions in plain language, tailored to their level of health literacy and cultural context (Haykal, 2025). For example, AI-powered apps allow users to upload images of skin lesions and receive clear, user-friendly explanations about possible conditions, symptoms, and next steps (Mohanty, 2024). These tools encourage proactive health management and prompt patients to seek professional care, when necessary, without replacing medical advice (Kania et al., 2024).

Remote monitoring systems further support patient education by tracking vital signs and alerting healthcare providers to potential issues. This not only enables earlier intervention but also reduces unnecessary visits to healthcare facilities. Importantly, AI increases transparency by providing patients with detailed information about their health status and treatments, which fosters trust and empowers patients about their care (Dave & Patel, 2023).

In the field of cosmetic dermatology, AI-powered educational tools such as the "Skincare Mirror" allow users to visualize the effects of different skincare products on their own skin. This interactive approach enhances engagement and learning, especially among users with little prior knowledge, such as men, who report high satisfaction with these tools (Kania et al., 2024).

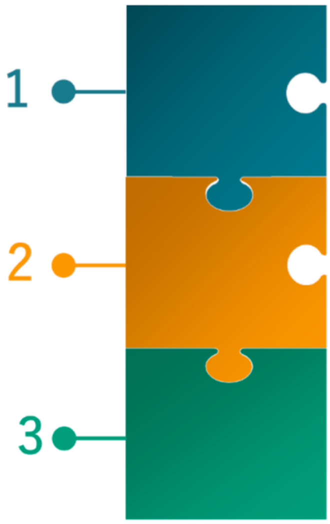
5.4.2. AI as an Educational Tool for Professionals

For healthcare professionals including pharmacists and cosmetologists, AI serves as a powerful catalyst for ongoing education and quality improvement. AI systems can continuously analyse the latest medical literature, providing timely updates and best-practice recommendations to help professionals stay current in their fields (Dave & Patel, 2023).

AI also plays a crucial role in professional development by monitoring and analysing provider performance, offering feedback, and identifying areas for improvement. Such feedback encourages self-reflection and fosters a culture of continuous quality enhancement (Dave & Patel, 2023).

In cosmetic dermatology, the effective integration of AI depends on practitioners being trained not only to use AI tools but also to interpret their outputs critically. This dual education: both technical and analytical is essential for safe and effective use of AI in clinical practice. Furthermore, collaboration between AI developers and healthcare professionals ensures that new tools are clinically relevant and tailored to real-world workflows (Thunga et al., 2024).

Highlights



AI supports the development of personalized and consistent skincare routines by analysing individual factors such as skin concerns, objectives, and preferences. Instead of offering isolated product suggestions, it delivers coherent recommendations that address the user's overall needs in a structured and targeted way.

By analysing ingredient databases, it identifies potential irritants and checks formulation compatibility with different skin types, surrounding environment, improving both safety and effectiveness.

These systems adapt over time based on user feedback and skin evolution, while also providing clear, personalized information to support consumers and professionals in their choices.

6. Case Study: L'Oréal – Artificial Intelligence in Personalized Skincare

As referred in the introduction, L'Oréal is a global leader in the cosmetics industry, displaying a strong international presence and a wide portfolio of brands spanning from skincare, makeup, haircare to fragrance. Its long-standing commitment to scientific research, innovation, and digital transformation has placed the group at the forefront of technological advances in beauty and dermatology. This is particularly evident in its integration of AI, now central to its vision of personalized and accessible cosmetic care (L'Oréal Paris and Modiface, 2025). The COVID-19 pandemic accelerated changes in consumer habits, especially the shift towards e-commerce. For companies like L'Oréal, traditionally reliant on physical retail, this marked a turning point. The brand responded by reinforcing its digital strategy and investing in AI-powered tools to deliver personalized skincare experiences online and in stores (Gilbert, 2021). L'Oréal's long-term AI strategy focuses on enhancing skin analysis, product personalization, and cosmetic education. The integration of these tools across digital and physical platforms optimizes the user experience while reinforcing the scientific rigor of its recommendations. This case study aims to explore how these tools work, the algorithms involved, and the benefits they offer to users (L'Oréal Paris and Modiface, 2025).

History

L'Oréal began its digital transformation in 2014 with the launch of Makeup Genius, an AR app that allowed users to virtually try on makeup marking the company's first major step into beauty tech. In 2018, L'Oréal acquired ModiFace, the first non-beauty brand to join its portfolio. ModiFace specializes in AI and AR technologies tailored for the beauty industry, offering advanced tools for makeup and hair virtual try-on, as well as skin diagnostics. Its precise facial tracking and real-time analysis gave L'Oréal a strong competitive edge and a solid foundation for scaling digital beauty services (Gilbert, 2021).

Three AI tools developed by L'Oréal will be discussed: Modiface, Vichy SkinConsultAI and Perso Device, as illustrated in Table 7:

Table 7: Comparison of L'Oréal's AI-Powered Devices.

	ModiFace	Vichy SkinConsult	Perso Device
Type	Web tool for skin analysis and virtual try-on	Online anti-aging diagnostic tool	Smart device for at-home skincare and makeup
Input	Selfies + clinical images	Selfies + dermatologist-classified image base	Selfies + environment + user preferences
Function	Detects skin features, recommends products	Assesses 7 aging signs, suggests routine	Creates custom skincare or makeup on demand
Tech	CNNs (image-based)	Deep learning + Skin Aging Atlas	CNN + sensors + AI blending system
Key Feature	Virtual try-on + clinical accuracy	Personalized anti-aging matrix + high precision	Real-time formulation tailored to skin and environment

Modiface:

L'Oréal's AI-powered skin diagnosis technology was developed in collaboration with ModiFace and relies on CNNs to analyse facial features from simple selfies. This system can generate a personalized skin assessment within seconds by detecting and quantifying multiple skin attributes, such as wrinkles, firmness, pigmentation, shine, pore size, uneven tone, and radiance. The algorithm is designed to operate effectively across diverse phototypes and age ranges, adapting its analysis to the user's unique skin characteristics (Hash et al., 2025).

L'Oréal's AI-powered tools enable users to upload a selfie and receive personalized product recommendations based on a detailed analysis of their skin profile. These systems rely on CNNs trained through a dual-phase approach. Initially, the algorithm was developed using 6,000 high-resolution clinical images collected from 4,000 individuals aged 20 to 80 across France, China, Japan, India, and the United States, as part of L'Oréal's proprietary Skin Aging Atlases. These atlases, the first comprehensive photographic standards for evaluating visible signs of aging, now serve as reference tools in the clinical assessment of cosmetic and dermatological treatments (L'Oréal Paris and Modiface, 2025).

To enhance real-world performance, the model was retrained using more than 4,500 smartphone selfies taken under various lighting conditions by women of Asian, Caucasian, and African American backgrounds. This additional training improved the algorithm's accuracy across a range of everyday scenarios, including variable light, facial expressions, and camera angles (L'Oréal Paris and Modiface, 2025).

A case study conducted in Denmark highlights the benefits of integrating AI-powered beauty tech at the point of purchase. In partnership with Matas, Denmark's leading health and beauty retailer, L'Oréal deployed ModiFace's VTO across all relevant product detail pages (PDPs). The web pages where consumers view product information and make purchase decisions. The goal was to enhance the shopping experience through personalized digital services while collecting insights on user behaviour and conversion (Gilbert, 2021). Figure 23 shows the results collected between 1st December 2020 and 4th May 2021, comparing ModiFace-enhanced PDPs with standard PDPs.

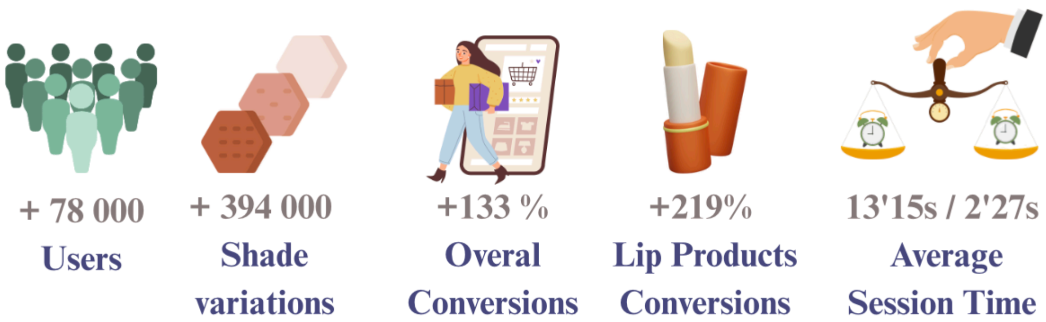


Figure 23: Key Performance Results from the ModiFace Implementation Case Study adapted from (Gilbert, 2021).

Studies evaluating the system have demonstrated a strong concordance between its automated assessments and those made by clinical dermatologists. This confirms the robustness of the model and its suitability for widespread use in both clinical and consumer settings (L'Oréal Paris and Modiface, 2025).

Vichy SkinConsultAI:

SkinConsult AI is one of L'Oréal's most advanced AI tools in dermatological diagnostics and personalized skincare. Developed by Vichy in collaboration with dermatologists and powered by ModiFace technology, the tool is based on more than 20 years of skin research and leverages the proprietary Skin Aging Atlas, a scientific reference built from over 15,000 dermatologist-classified images representing diverse skin tones, ages, and concerns (VICHY laboratoires, 2025).

Launched in 2019, SkinConsult AI functions as a virtual anti-aging and skincare simulation tool, accessible through the Vichy website. It uses deep learning algorithms trained on millions of facial images to analyze visible signs of skin aging. The system operates in three steps as illustrated in Figure 24: 1) Users upload a selfie; 2) The AI evaluates seven key skin attributes: under-eye wrinkles, fine lines, deep wrinkles, lack of firmness, dullness, dark spots, and pore visibility; 3) Generates a personalized aging matrix highlighting both the skin's strengths and the areas needing targeted care (Elder et al., 2024; L'Oréal Paris, 2025).

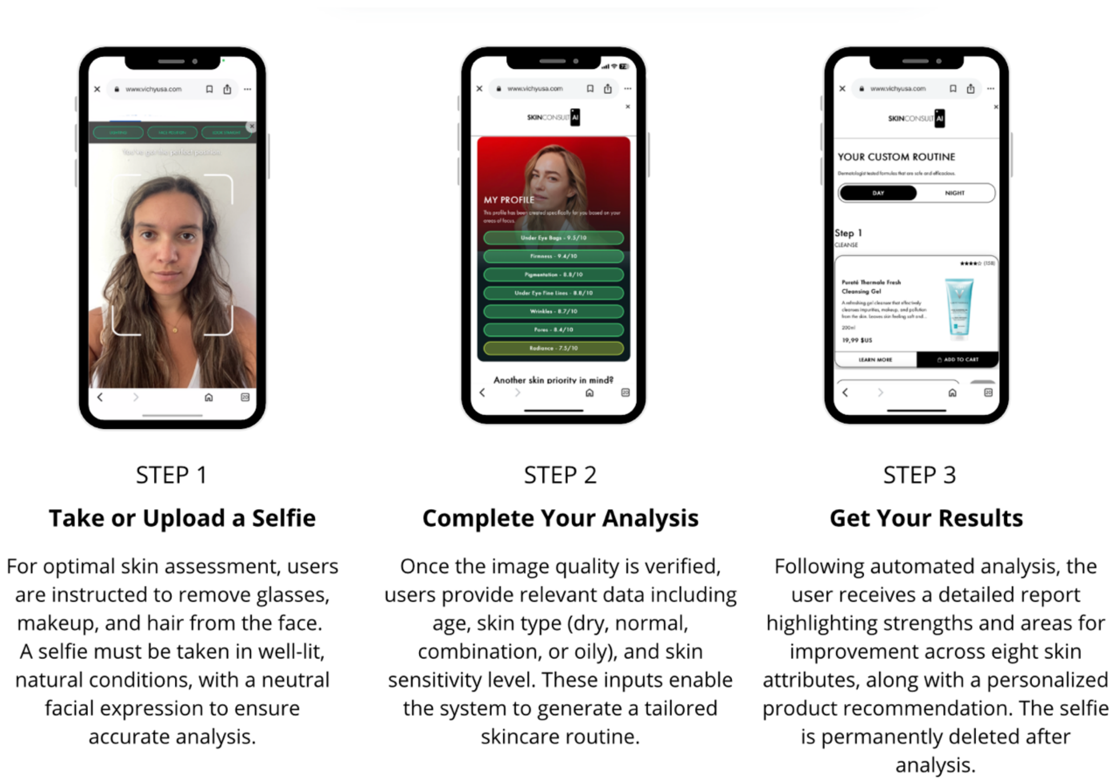


Figure 24: Three-Step AI Skin Analysis Process, adapted from (VICHY laboratoires, 2025).

Personalized Product Recommendations: Based on the previous analysis, the system provides a fully customized skincare routine aligned with each woman's unique skin priorities. This process is powered by algorithms that match clinical indicators with product data, leveraging a hybrid model that incorporates content-based filtering and personalized profiling. The output is a coherent product sequence adapted to skin condition and user goals (Hash et al., 2025; L'Oréal Paris, 2025).

To ensure accuracy in real-world conditions, the model was retrained on over 4,500 smartphone selfies taken under varied lighting conditions by women of different ethnicities, improving its performance across diverse use cases (Elder et al., 2024). The result is a diagnostic precision of over 95%, making it comparable to a dermatologist consultation and accessible to users of all ages and skin types (VICHY laboratoires, 2025).

In addition to analysis, the tool provides personalized product and routine recommendations, guiding users, especially first-time skincare buyers, toward suitable solutions. When combined with an e-consultation, this experience becomes even more reliable and user-friendly (Gilbert, 2021). By integrating this tool across several L'Oréal brands, SkinConsult AI exemplifies the Group's commitment to scientific rigor, AI innovation, and accessible, individualized beauty care (VICHY laboratoires, 2025).

Perso Device:

L'Oréal's innovation goes further with the Perso device. It illustrates the brand's most advanced application of AI in personalized skincare. Introduced at the Consumer Electronics Show in 2020, Perso is a handheld smart device designed for at-home use that leverages ModiFace technology to analyse user selfies taken through a mobile application (Elder et al., 2021). The system evaluates various facial attributes, including deep wrinkles, fine lines, dark spots, and pore visibility, offering a comprehensive skin profile based on visual input (L'Oréal Groupe, 2025).

In addition to image-based diagnostics, Perso integrates Breezometer geo-location data to assess environmental factors that affect skin health, such as UV index, humidity, temperature, and pollen levels (Elder et al., 2021). The user is also prompted to input personal skincare goals, which are used in combination with biometric and environmental data to generate a customized blend of high-performance skincare. These formulations are dispensed in precisely dosed single applications, tailored to each user's current skin condition and context (L'Oréal Groupe, 2025).

Expanding beyond skincare, Perso can also create custom foundations and lipsticks, adapting color and texture in real time to match the user's needs (Hash et al., 2025). This multifaceted functionality highlights L'Oréal's broader vision of hyper-personalized beauty, where AI adapts to each individual's biology, preferences, and environment. As these technologies evolve, they continue to incorporate more diverse data sources, allowing for increasingly refined and inclusive recommendations reinforcing L'Oréal's leadership in beauty tech innovation (Hash et al., 2025; L'Oréal Groupe, 2025).

Patient Education through AI

Beyond diagnosis and product matching, L'Oréal's AI tools serve as educational interfaces. Modiface and SkinConsultAI platforms provide visual simulations of the skin's future state with continued product use. These immersive tools are particularly beneficial for individuals with limited skincare knowledge, increasing engagement and satisfaction (Kania et al., 2024; L'Oréal Paris and Modiface, 2025).

The platforms offer clear explanations of how the skin is analyzed, which ingredients are most appropriate, and how to integrate products into a routine. In doing so, they serve as ongoing educational support that promotes autonomy, adherence, and deeper understanding of skincare science (Kania et al., 2024).

7. Limitations and challenges

7.1. Technological, ethical and scientific limitations

a) Data Quality, Bias, and Representation

AI in cosmetology is highly dependent on the quality, diversity, and representativeness of the datasets used to train algorithms. Inaccurate, imbalanced, or incomplete data can lead to flawed or biased outputs (Georgievskaya et al., 2023). For instance, a beauty contest judged by AI selected only light-skinned women, illustrating the underrepresentation of darker skin tones and the discriminatory consequences that may result (Fliorent et al., 2024).

AI systems often reflect cultural, demographic, and gender-related biases present in training sets. Models predominantly trained on light-skinned individuals can generate inappropriate recommendations for people with darker skin (Elder et al., 2024; Salminen et al., 2023). The Fitzpatrick scale has also been shown to over represent type IV skin among black individuals, thus causing diagnostic inaccuracies (Fliorent et al., 2024).

Additionally, gender and age-related biases may ignore hormonal variations or promote unrealistic beauty standards, marginalizing users whose profiles are underrepresented (Georgievskaya et al., 2023; Salminen et al., 2023).

b) Input Variability and Generalization Limits

Measurement inconsistencies, caused by differences in imaging devices, lighting conditions, or photo quality, significantly affect AI performance. Such input variability limits reproducibility and generalizability in real-world settings, especially outside controlled environments (Thunga et al., 2024). Subjective human scoring during model training or evaluation introduces further variability, compromising model reliability and weakening comparative studies between tools (Kania et al., 2024).

c) Opacity and Ethical Gaps in Cosmetic AI

Many AI systems in cosmetology operate as “black boxes”, offering limited insight into their decision-making processes. While some models reach high accuracy, their opacity undermines user trust and raises safety concerns. The inability to explain how diagnoses or treatment suggestions are made may result in unforeseen consequences during practical application (Kania et al., 2024).

In contrast to clinical settings, where patient protection is governed by ethical protocols: cosmetic AI tools often lack ethical oversight. This leads to insufficient regulation regarding how data are used, how decisions are justified, and how patient well-being is considered (Abu Hammour et al., 2023; Hasan et al., 2024).

d) Insufficient Clinical Validation

Many cosmetic AI tools lack rigorous clinical evaluation. There are few standardized protocols for validating their performance, especially for measuring skin parameters like pigmentation, sebum, or wrinkles across diverse populations. The absence of benchmark standards limits scientific credibility and confidence in their long-term application (Kania et al., 2024).

e) Data Privacy and Informed Consent

AI tools in beauty often process sensitive personal data such as facial images, biometric markers, and even behavioural patterns (Grech et al., 2024). These data are frequently stored on third-party servers, with risks of unauthorized access, misuse, or marketing exploitation without explicit user consent (Thunga et al., 2024).

This is particularly concerning in cosmetics, where regulations are often less stringent than in clinical practice. Ethical use of AI requires transparent consent procedures, robust cybersecurity, and user control over how personal data are handled (Grech et al., 2024).

f) Limited Access and Digital Inequality

The use of advanced AI tools in skincare is often limited to individuals with access to smartphones, stable internet, or high-end beauty devices. This creates a disparity in availability and usability, particularly for populations with limited technological resources (Fliorent et al., 2024). Such digital inequalities may exclude certain user groups from benefiting from personalized skincare or education, reinforcing systemic barriers already present in healthcare and beauty services (Georgievskaya et al., 2023; Grech et al., 2024).

7.2. Acceptance by professionals and users:

a) Confidence in AI-Driven Care

One of the main challenges in integrating AI into healthcare practice, is the level of trust that professionals place in these technologies (Shevtsova et al., 2024). Many clinicians remain sceptical, particularly when dealing with complex algorithms whose internal logic is not easily understandable. These so-called “black box” systems can raise concerns, as healthcare professionals often prefer tools that offer transparent reasoning and traceable decision-making processes (Jiang et al., 2018).

This lack of trust is further reinforced in medical fields where clinical judgment relies heavily on intuition, experience, and nuanced decision-making: factors that are difficult to replicate by technology. Another key concern involves accountability: in the event of an error or incorrect recommendation, it is often unclear who bears responsibility, whether it’s the developer, the algorithm, or the healthcare provider (Jiang et al., 2018).

b) Developing Competence in AI Use

The acceptance of AI in healthcare depends strongly on the level of education and training provided to professionals. Many pharmacists still feel unprepared to work with AI due to a lack of exposure to relevant concepts during their studies. Including AI-related topics such as data literacy, algorithm interpretation, and ethical considerations in pharmacy education helps develop the confidence and skills needed to interact effectively with these tools (Cain et al., 2023). Insufficient training and limited exposure to AI tools can severely slow down their integration into routine healthcare workflows (Shevtsova et al., 2024). When properly trained, professionals are more likely to trust AI and integrate it into their practice. In this sense, training plays a crucial role not only in technical adaptation, but also in building trust and promoting a positive attitude toward innovation (Cain et al., 2023).

c) Trust and Acceptance Among End Users

The acceptance of AI by patients in cosmetology and pharmacy practice depends on a balance between perceived benefits, potential risks, and personal factors. Many individuals recognize AI's capacity to improve diagnostics, tailor treatments, and enhance overall care. However, their comfort largely depends on the context of use and the way AI is incorporated into the care process (Alowais et al., 2023). Trust, transparency, and clear communication are key: patients feel more reassured when AI tools are used under professional supervision and when they understand how these technologies function and how their personal data is managed (Shevtsova et al., 2024; Young et al., 2021).

d) Influential Factors in AI Adoption

Several factors such as age, education level, prior exposure to technology, and personal health experience can influence acceptance. Some patients remain hesitant, particularly due to concerns about misdiagnosis, loss of human connection, or data misuse (Alowais et al., 2023). These concerns highlight the need to involve patients actively, ensuring that they are properly informed and reassured about the use of AI. In this way, education and communication become central to building trust. Ultimately, while AI is often seen as a valuable innovation, its successful adoption depends on maintaining human oversight and reinforcing the patient–provider relationship (Young et al., 2021).

7.3. Future Directions of AI in Cosmetology

AI is poised to revolutionize the future of cosmetology by driving hyper-personalization, accelerating research, and supporting sustainable innovation. As AI technologies mature, they are expected to go beyond current diagnostic and recommendation systems, offering deeply tailored beauty experiences that dynamically adapt to everyone's evolving needs. The concept of personalization is moving from static product suggestions to predictive, data-driven formulation creation, in which AI develops unique solutions based on biometric, environmental, and behavioural data (Charllo, 2022; Jabraeili, 2025).

One of the most promising directions lies in the enhancement of aesthetic consultations through AI. Technologies based on computer vision and 3D modelling are expected to elevate the quality of professional assessments by improving visual analysis, aligning procedures with patient expectations, and increasing engagement during decision-making (Eppler & Ma, 2025). Additionally, the growing use of iOS-based diagnostic tools offering functionality similar to traditional skin analysis systems without requiring heavy investment makes high-resolution evaluation more accessible in both clinics and home settings (Elder et al., 2021).

One of the most promising developments is the use of generative AI to create new product formulations on demand. Rather than recommending from a fixed catalogue, AI could generate entirely bespoke formulations, co-designed with the consumer and aligned with their skin profile, environmental exposure, and preferences. This opens the door to hyper-personalized cosmetics and potentially enables new business models such as on-demand production and 3D printing of skincare products (Eppler & Ma, 2025).

In research and development, AI is expected to play a central role by enhancing formulation optimization and accelerating ingredient discovery. With the integration of multi-omics data such as genomics and proteomics: AI can help identify new active compounds, understand their biological pathways, and predict their efficacy. This approach deepens scientific understanding and supports the creation of more effective and targeted cosmetic treatments (Jabraeili, 2025). As data availability continues to grow, AI models will become increasingly accurate and reliable, further improving the efficiency and precision of product development (Eppler & Ma, 2025).

The future of AI in cosmetology will also depend on inclusive, ethical, and transparent implementation. As AI becomes more integrated into beauty routines, it will be essential for brands to maintain user trust through explainable algorithms, data protection, and responsible practices. Interdisciplinary collaboration between scientists, data engineers, formulators, and ethicists will be key to ensuring that AI's potential is fully realized while respecting the values and safety of consumers (Charllo, 2022; Eppler & Ma, 2025).

In sum, the coming years are expected to see AI evolve from a supportive tool to a transformative force across all stages of the cosmetic value chain: from research and formulation to customer experience and sustainability. Brands that embrace these advances with innovation, responsibility, and transparency will shape the future of beauty as both high-tech and human-centered (Charllo, 2022).

To synthesize the current landscape of AI in cosmetic dermatology, a SWOT analysis was carried out. This framework briefly outlines the key strengths, weaknesses, opportunities, and threats associated with the integration of AI technologies into skincare practice.

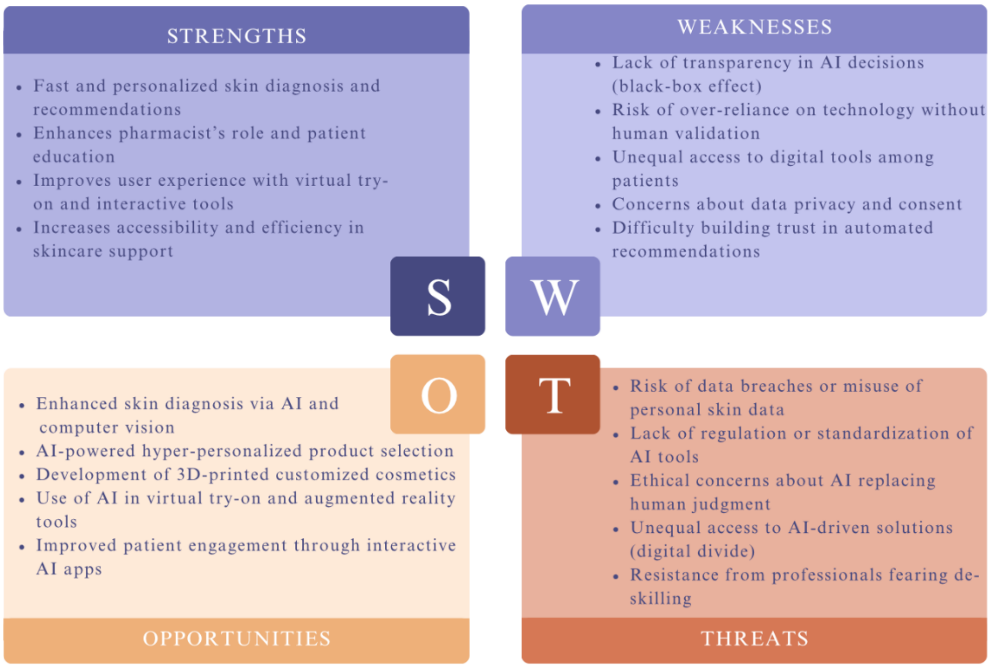


Figure 25: SWOT analysis of AI integration in skincare practise.

8. Conclusion

AI is increasingly shaping the future of cosmetology by enabling a more precise, personalized, and connected approach to skincare. Its integration into the beauty industry has marked a paradigm shift, allowing brands to go beyond traditional cosmetic formulation and offer tailored solutions based on individual needs. The use of advanced diagnostic tools powered by computer vision and ML has enhanced skin analysis capabilities, making it possible to detect a wide range of skin conditions remotely and non-invasively. This evolution supports a more proactive and preventive vision of skincare.

Companies like L'Oréal have positioned themselves at the forefront of this transformation. By investing in AI-powered tools such as virtual try-on applications and diagnostic platforms, they have democratized access to dermatological insights and enhanced user engagement. These technologies not only facilitate personalized product recommendations but also foster customer loyalty by improving the accuracy and relevance of the products offered.

Another important implication of AI is its growing role in pharmacy practice. As patients become increasingly empowered and informed, pharmacists are expected to provide more personalized advice, particularly regarding dermo cosmetic care. With proper training in digital tools and algorithmic reasoning, pharmacists can guide consumers through AI-generated recommendations, reinforcing trust in the healthcare system. Thus, integrating AI education into pharmacy curricula becomes a strategic priority to prepare future professionals for this digital transition.

Looking ahead, the future of AI in cosmetology is rich with opportunity. The emergence of generative AI may allow for the creation of entirely customized products, while the use of multi-omics data could accelerate the discovery of new active ingredients and mechanisms of action. Moreover, wearable technologies and environmental sensors are expected to be integrated into future skincare routines, providing real-time insights and hyper-personalized care. These advancements will likely redefine the standard of care, combining scientific rigor with user-friendly experiences.

Far from being a passing trend, AI is establishing itself as a powerful tool for innovation and inclusivity in the beauty sector. If deployed responsibly with transparent communication, ethical data practices, and ongoing human oversight. AI has the potential to make skincare more effective, accessible, and adaptive to the needs of every individual.

To conclude this thesis, Figure 26 provides a strategic overview of the main factors shaping the implementation and future development of AI-driven skincare solutions.

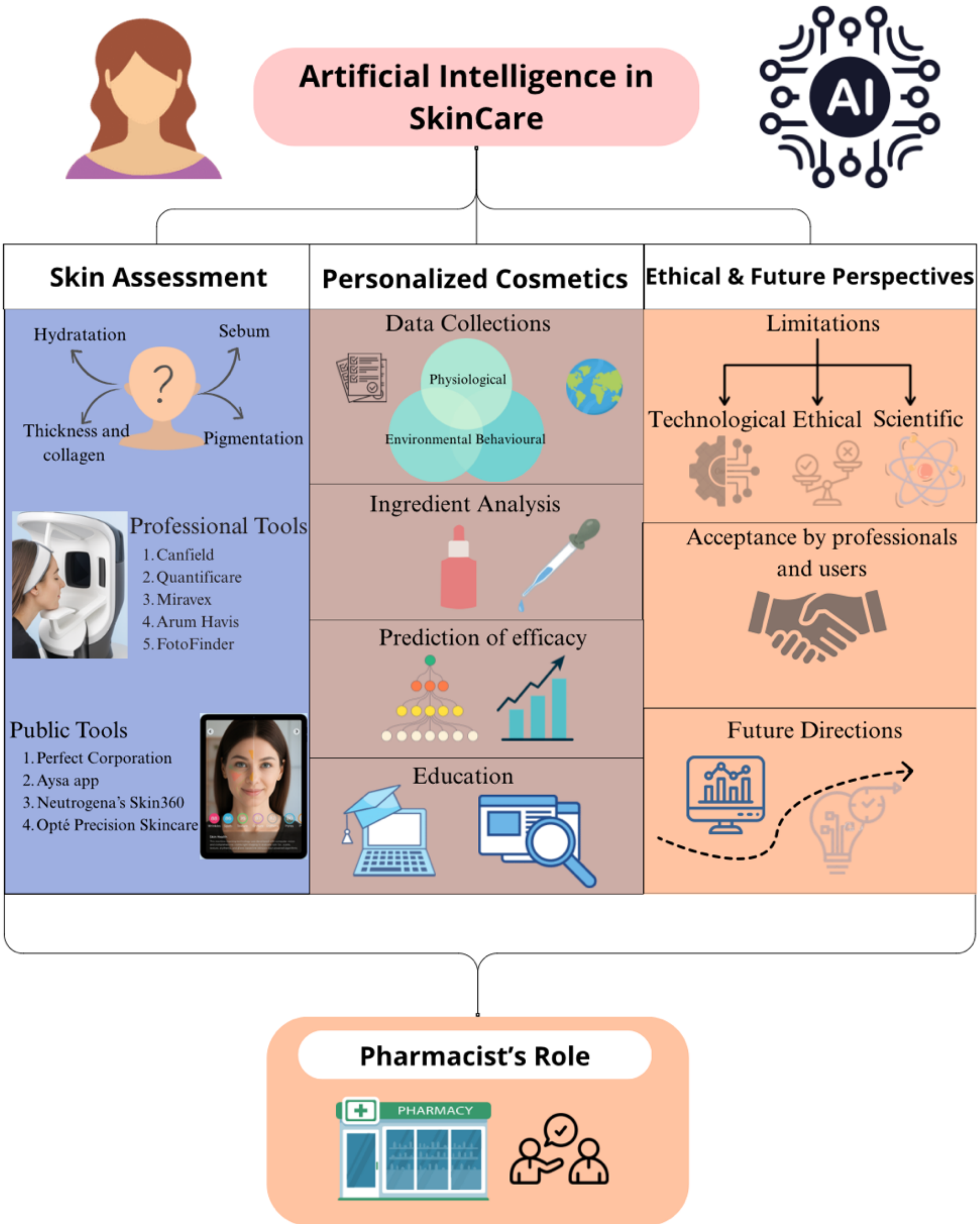


Figure 26: Graphical Abstract, made with Canva.

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mar. 17 juin 11:30

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Guido Mariotto <guido@miravex.com>
À moi
mar. 17 juin 15:03

Dear Marine,

Thank you for your note and introduction. Please take this e-mail as our authorisation to use images on our website for your thesis. If you need high resolution copies, we will be happy to send them.

Best of luck with your thesis!

Guido

PS
Your thesis sounds interesting, I wouldn't mind perusing through it once you graduate. If that's alright with you, kindly send me an electronic copy :)

—

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hyun <hyun@aramhuvis.com>
À moi, info

Dear Marine,

Thank you for your kind email below.

We provide consent to usse images. Hope you have a good result.

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