Ángeles Álvarez Hermida.
Advanced Practice Nurse in Diabetes.
Family and Community Nurse Specialist. CS Goya. Madrid, Spain.

Olga Gómez Ramón.
Advanced Practice Nurse in Diabetes.
Family and Community Nurse Specialist. Xarxa Sanitaria, Social y Docente de Santa Tecla.

Education with (artificial) intelligence:

the future is already in the clinic

1. INTRODUCTION: THE DUAL CHALLENGE OF DIABETES AND ITS EDUCATION

In daily clinical practice, the escalating prevalence of type 2 diabetes (T2DM) represents a major challenge, consolidating its position as one of the most pressing epidemics of our time. The figures are compelling: in 2021, 537 million people worldwide were living with diabetes, a number projected to reach 783 million by 2045.

In Spain, the situation is equally alarming, with 5.1 million affected individuals, representing **14.8% of the population** (1).

This high prevalence imposes a devastating economic burden—estimated at $327 billion globally and €966 million in Spain—and exposes people with diabetes to a heightened risk of severe complications such as diabetic retinopathy and cardiovascular disease (1).

In this complex scenario, Diabetes The- »

rapeutic Education (DTE), also known as DSMES *(Diabetes Self-Management Education and Support)*, emerges as a fundamental and irreplaceable pillar of treatment. Its clinical impact is well established, achieving reductions in glycated hemoglobin (HbA1c) of 0.3% to 2.0%, decreasing the risk of complications by 30%–40%, and improving treatment adherence by 40%–60% (2).

Despite its proven efficacy, the traditional DTE model faces significant barriers limiting its reach: scarcity of specialized educators, standardized programs with limited personalization, and geographic or scheduling constraints that hinder access. In this context, Artificial Intelligence (AI) emerges as a transformative tool capable of overcoming these limitations by offering highly personalized, scalable, and continuously accessible educational solutions (3, 4, 5).

2. THE TRANSFORMATIVE POTENTIAL OF AI IN DTE

AI offers a new approach to DTE by directly addressing the shortcomings of the traditional model. Its intrinsic capabilities—24/7 education and support, massive scalability, real-time adaptation to individual needs, and complex health data pattern analysis—precisely respond to the challenges of availability, personalization, and access.

The application of AI in diabetes management is multifaceted and encompasses an interconnected ecosystem of tools designed to enhance self-care and prevent complications (3):

* **RAG Chatbots:** Virtual assistants that, unlike traditional language models that may "hallucinate" (generate inaccurate or fabricated information), use *Retrieval-Augmented Generation* architecture to base responses on verified medical knowledge sources, ensuring safety.

* **Mobile Applications:** Interactive platforms integrating educational modules, monitoring tools, and communication channels with health professionals, facilitating daily self-management.

* **Continuous Glucose Monitoring (CGM) With AI:** Systems that analyze glucose sensor data to predict trends, detect individual patterns, and proactively alert for potential hypo- or hyperglycemia (6).

* **Computer Vision:** Algorithms trained to analyze medical images and automatically detect complications such as diabetic retinopathy or diabetic foot ulcers with accuracy comparable to trained professionals.

* ***Wearables and Internet of Things (IoT)*:** Noninvasive devices monitoring multiple physiological parameters. Their data feed more sophisticated tools such as AI-integrated CGM, creating a holistic view of the individual's health.

* **AI-Enhanced Telemedicine:** Remote care platforms integrating AI tools to analyze patient data in real time, prioritize cases, and facilitate continuous and efficient follow-up.

While the technical capabilities of these tools are impressive, their true value lies in measurable clinical outcomes, where an increasingly robust body of evidence is emerging.

3. CLINICAL EVIDENCE FOR MAIN AI MODALITIES

The scientific evidence supporting AI in diabetes management is steadily strengthening. The most consistently evaluated clinical indicator is HbA1c reduction, with digital interventions demonstrating significant benefits, though with variable effectiveness depending on modality, ranging from 0.32% to 0.54%.

Mobile applications rank at the higher end of effectiveness, achieving HbA1c reductions between 0.32% and 0.54%. In addition to clinical impact, they demonstrate notable cost-effectiveness, with an average cost per person of $269 vs $465 for face-to-face interventions[7]. RAG chatbots democratize access to reliable 24/7 information. Although their direct impact on HbA1c is more modest (approximately 0.32%), their 94% accuracy rate in source-attributed responses makes them a consistent and safe support resource (8).

The integration of CGM with AI represents a qualitative leap, achieving HbA1c reductions of up to 0.54%. Its ability to predict glucose levels 30 to 120 minutes in advance allows

THE INTEGRATION OF CONTINUOUS GLUCOSE MONITORING (CGM) WITH ARTIFICIAL INTELLIGENCE (AI) REPRESENTS A QUALITATIVE LEAP, ACHIEVING HBA1C REDUCTIONS OF UP TO 0.54%. ITS ABILITY TO PREDICT GLUCOSE LEVELS 30 TO 120 MINUTES IN ADVANCE ENABLES PROACTIVE ADJUSTMENTS

proactive adjustments. Additionally, it plays a critical role in early detection of glycemic dysfunction by identifying a fasting glucose threshold of 88 mg/dL associated with a 2-fold increased risk of developing T2DM (6).

In complication detection, computer vision has demonstrated diagnostic accuracy for diabetic retinopathy comparable to trained ophthalmologists, facilitating large-scale screening (9). For diabetic foot prevention, hybrid models (CNN-RNN) and thermography achieve ulcer detection accuracy of 85%–95%. Innovative tools such as smart podometric mats can predict ulcer development up to 37 days in advance with 97% accuracy, creating opportunities for preventive intervention (10).

The clinical impact of these tools is undeniable. However, their large-scale implementation is not without significant technical, social, and ethical challenges that must be carefully considered.

4. CHALLENGES AND ETHICAL CONSIDERATIONS IN IMPLEMENTATION

The integration of AI into clinical practice goes beyond a purely technical challenge; it confronts us with profound ethical and social considerations. For the adoption of these technologies to be successful, equitable, and sustainable, it is necessary to proactively address the barriers that could limit their potential or, worse, amplify existing health inequalities.

A) **Interpretability and trust ("black box"):** Many of the most powerful deep learning models operate as a "black box," without allowing us to trace the logical reasoning underlying a recommendation. From a clinical perspective, this is unacceptable. As health care professionals, we bear the legal and ethical responsibility for every decision. Delegating that responsibility to an algorithm whose internal functioning we cannot explain generates justified distrust and represents a fundamental barrier to adoption.

B) **Equity and algorithmic bias:** Algorithms learn from the data on which they are trained. If these data are not representative of population diversity (excluding ethnic minorities, women, or older adults), the resulting models may perform less accurately in these groups, perpetuating or even exacerbating existing health disparities.

C) **Digital gap:** Unequal access to technology—device costs, internet connectivity, and digital literacy—constitutes a major barrier. It may exclude the most vulnerable populations, often those who would benefit most from these innovations, concentrating their advantages among already privileged groups.

D) Adherence and the human factor: Digital interventions frequently encounter declining long-term adherence. Technology alone cannot replace human connection. A key statistic shows that 88% of individuals with diabetes would trust an AI system only if supervised by a health professional[11]. The most significant challenge is decreasing adherence over time, with studies demonstrating a drop in usage from 92% initially to 57% at 6 months (8).

This underscores the irreplaceable need for supervision, clinical judgment, and empathy that only a health professional can provide.

These challenges do not invalidate the potential of AI; rather, they guide us toward the most logical and safest solution: a collaborative model integrating the best of technology and human care.

5. TOWARD A HYBRID AND ETHICAL MODEL

AI has strong potential to transform diabetes therapeutic education.

However, the future of DTE does not lie in replacing professionals with algorithms, but in creating a synergistic hybrid model. This is not merely a preference but a clinical necessity: 88% of individuals with diabetes trust AI only under professional supervision[11]. AI provides data analysis, scalable personalization, and continuous support, while the professional offers what is irreplaceable—empathy, clinical judgment, motivational support, and a trusting relationship.

To implement this model, we must be careful and selective, choosing tools supported by solid evidence, training professionals, and designing equitable systems that reduce the digital divide. The goal is to use technology to enhance human interaction, freeing professional time for what no machine will ever be able to do: care for people. D

CONCLUSIONS

AI is already transforming diabetes therapeutic education, delivering measurable and clinically relevant outcomes.

Evidence demonstrates improvements in glycemic control, prevention of complications, and system efficiency.

Its true value lies not in replacing professionals, but in strengthening their educational and clinical capacity.

Ethical challenges include algorithmic bias, the digital divide, and the need for interpretability; therefore, ethical implementation requires transparency, equity, and professional training to prevent new inequalities.

A hybrid AI–professional model is essential to ensure trust and long-term adherence.

REFERENCES

1. International Diabetes Federation. IDF Diabetes Atlas. 11th ed. 2025.
2. American Diabetes Association Professional Practice Committee. Standards of Care in Diabetes—2025. Diabetes Care. 2025;48(Suppl 1):S86–S127.
3. Li C, Li W, Shao Y, et al. A Scoping Review of Artificial Intelligence-Based Health Education Interventions for Patients with Type 2 Diabetes. Diabetes Metab Syndr Obes. 2025 Sep 19;18:3539–3552.
4. Corrao S, Janić M, Maggio V, Rizzo M. Machine learning and deep learning in diabetology: revolutionizing diabetes care. Front Clin Diabetes Healthc. 2025 May 27;6:1547689.
5. Vehi J, et al. Generative artificial intelligence in diabetes healthcare. iScience. 2025;28(5):110312.
6. Ji C, Jiang T, Liu L, Zhang J, You L. Continuous glucose monitoring combined with artificial intelligence: redefining the pathway for prediabetes management. Front Endocrinol (Lausanne). 2025 May 26;16:1571362.
7. Xue H, Zhang L, Shi Y, et al. The effectiveness of digital health intervention on glycemic control and physical activity in patients with type 2 diabetes: a systematic review and meta-analysis. Front Digit Health. 2025 Jul 29;7:1630588.
8. Kelly A, Noctor E, Ryan L, van de Ven P. The Effectiveness of a Custom AI Chatbot for Type 2 Diabetes Mellitus Health Literacy: Development and Evaluation Study. J Med Internet Res. 2025 May 5;27(1):e70131.
9. Akhtar S, et al. A deep learning based model for diabetic retinopathy grading. Nat Sci Rep. 2025;15:87171.
10. Misir A, et al. Artificial Intelligence and Machine Learning in Diabetic Foot Ulcer Care. J Diabetes Sci Technol. 2025;19(1):1363632.
11. Alzghaibi H, et al. Perspectives of people with diabetes on AI-integrated wearable devices. Front Med. 2025;12:1563003.