MEGA
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TRENDS
2025

BEYOND THE FUTURE

CONTENT

INTRO-DUCTION

"If I have seen further, it is by standing on the shoulders of giants."

In 1676, Isaac Newton penned this phrase as a subtle jab at his rival Robert Hooke, who was notably short in stature. Beyond the irony, the phrase perfectly captures the essence of innovation: every breakthrough is built upon previous knowledge.

Without Turing's machine, there would be no artificial intelligence. Had Newton not observed the fall of an apple—or drawn inspiration from Hooke's work—computer science might never have emerged. Without Pythagoras, Newton likely wouldn't have been able to describe gravity.
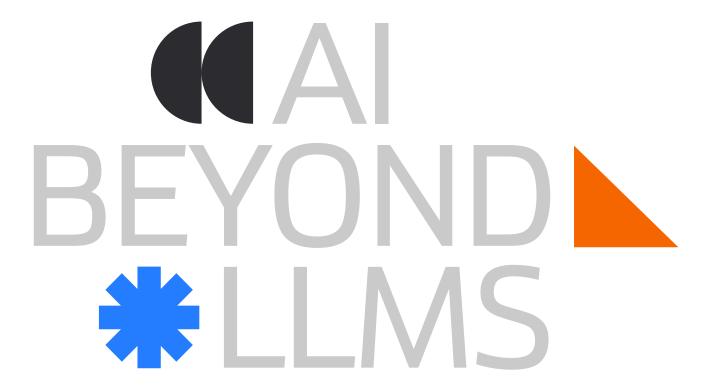
Understanding the trajectory of scientific and technological progress—from observation to application—is essential to anticipating the future. That is precisely what we asked the experts of the Future Trends Forum, a think tank promoted by the Bankinter Foundation of Innovation.

We turned to these global experts for the perspective needed to look ahead. Their deep knowledge across disciplines helps us understand the innovative paths that will shape the future and the road we must travel to get there.

The ten trends outlined in this *Megatrends 2025* report span diverse fields of innovation, each with the potential to transform our lives. From artificial intelligence to quantum computing, from precision medicine to the enhancement of human capabilities through neurotechnology, we are already climbing the rungs that will support tomorrow's evolution.

These expert insights also allow us to track how these trends have progressed since the previous edition of the report. Where do we stand now? What can we expect from each trend?

What lies beyond large language models? How will quantum breakthroughs reshape industries? What tangible benefits will space exploration bring? What will future cities look like? How will healthcare evolve? *Megatrends 2025* explores these and many other questions.

Understanding the trajectory of scientific and technological progress—from observation to application—is essential to anticipating the future.

TREND 1

AI BEYOND LLMS

Evolution and Real-World Impact

A Da Vinci robot performs a delicate suture, mimicking the hand of a skilled surgeon. It has trained by watching surgical videos and acts independently. When the needle falls, it improvises—and succeeds. It calmly picks up the needle and continues the operation.

This is the frontier of artificial intelligence: solving complex tasks, adapting to different environments, and doing so reliably and ethically.

✳ Think Like Us

Generative AI is evolving beyond mere pattern replication. Large language models (LLMs) are increasingly capable of emulating human reasoning.

The next step is to prompt machines to think like we do. This is the foundation of "chain-of-thought" (CoT) prompting. Models like OpenAI's o1 or China's Deepseek R-1 demonstrate this by breaking down problems into logical, sequential steps—as if solving a math problem aloud.

Now the goal is to accelerate and optimize this process. Meta's COCONUT (Continuous Chain of Thought) aims to allow models to reason without relying on language alone.

✳ Go Beyond My Reach

LLMs are just the beginning. Smaller, domain-specific models are already transforming industries.

As anticipated in *Megatrends 2024*, vertical AI is poised to revolutionize sectors. A highly specialized AI has successfully designed one of the most complex engines in the aerospace industry. Microsoft's MatterGen doesn't search for existing materials—it creates them from scratch.

What happens when AI integrates with neuromorphic chips? What will predictive quantum software look like? And do we have the talent to build it?

A highly specialized AI has successfully designed one of the most complex engines in the aerospace industry.

✳ Act the Way I Would

Autonomous agents are AI systems that learn, act, and make decisions based on environmental input. Today, these agents support customer service, logistics, and sales teams by prioritizing leads, answering queries, and resolving disruptions.

As robotics and sensors evolve, collaboration between machines and humans in complex environments will become standard. Autonomous mobile agents and cognitive cobots—robots that learn from their surroundings and adapt in real time—are already being developed by startups.

This shift marks the evolution from large language models to large action models, optimized for decision-making and execution. Google refers to this as the new "agency era."

✳ Behave Like a Human

The next frontier is embodied AI and humanoid robots. In Shanghai, robots are training to paint cars or serve food with striking precision. Tesla's robotaxis are pushing the boundaries of machine embodiment.

These machines evoke a mix of awe and unease. While their human form may ease interaction, it can also blur ethical boundaries.
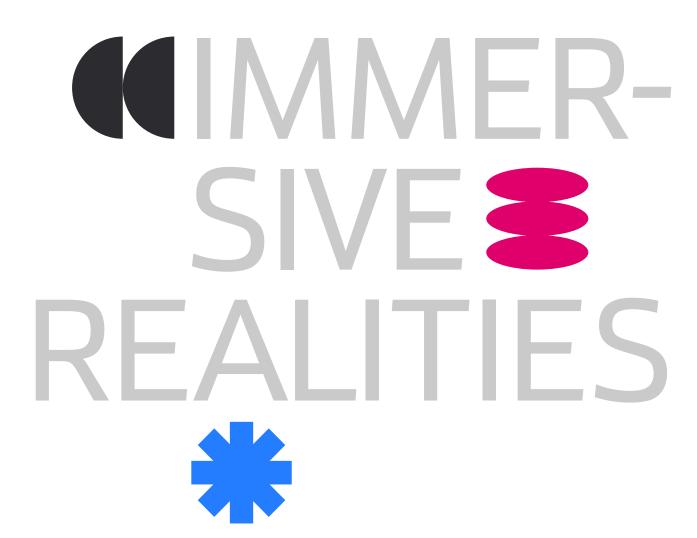
By 2027, only 1,000 humanoids are expected to be trained in one facility. What happens next? Can they work in real restaurants? How will they respond to moral dilemmas, such as during a robbery? Will we converse with them like humans?

These questions touch on broader implications for employment, regulation, and social norms. Aligning AI with human interests requires equitable access and avoiding monopolies. Experts advocate global governance and digital sovereignty as paths to ensure ethical development.

AI must not only be productive, but fundamentally ethical and safe. A surgical robot must do more than suture well—it must always prioritize the patient's best interest.

Training autonomous agents, ensuring workplace safety, and developing assistive humanoids are just a few opportunities that lie ahead.

Who will be accountable for an autonomous agent's actions? How will we communicate with humanoids? What form will a robot's Hippocratic oath take?

TREND 2

IMMER-SIVE REALITIES

Redefining Human Interaction and Digital Environments

From watching a movie to deciding how its plot unfolds in real time. From testing a product to configuring its digital twin. From playing a video game with physical gestures to generating it with thoughts and emotions.

As stated in Megatrends 2024, immersive technologies are poised to transform entire industries. They will redefine how we experience the world, revolutionizing sectors, business models, and everyday life.

✳ From Thumbs to Augmented Intelligence

Our interactions with electronic devices have long relied on a key human feature: the opposable thumb. We've used it to operate tools, switch TV channels, play games, and type messages.

In the near future, our default interface with computers and smartphones will shift. Interaction will depend less on our thumbs and more on our nervous systems.

Advancements in neurotechnology, sensing, immersive tech, and AI will blur the boundaries between physical and digital. This new form of augmented intelligence will enable machines to detect and adapt to our reactions, offering tailored experiences in the form of virtual, augmented, mixed, or extended reality.

Video games that respond to mood or neural signals. Customers configuring a car through its digital twin. These are just a glimpse of what lies ahead.

✳ A New Paradigm

The key to moving beyond the physical limits of devices lies in spatial computing. This approach will lay the foundation for machines to better understand and interact with us.

Apple's Vision Pro is already described as its first spatial computer. Meta has licensed its Horizon OS to hardware makers like Lenovo and Asus, and has created frameworks for mixed reality developers. Its Orion smart glasses, while discreet, already integrate basic augmented reality.

These advances are enabling a virtual environment economy. Digital assets, immersive marketplaces, and economic metaverses are on the horizon.

In this new paradigm, geography gives way to temporality. As physical and digital boundaries blur, so too will conventional concepts like time zones. We'll measure distance in hours, not kilometers.

To succeed, companies must transition from local and physical models to flexible, virtual ones. It will be worth the effort: real-time data delivered through AR will improve critical decision-making.

✳ Creation Without Limits

Immersive technology's creative potential is amplified by AI. Real-time creation of music, video, and 3D environments is accelerating thanks to generative AI.

As noted in *Megatrends 2024*, AI's role in programming and immersive video creation will multiply the possibilities of digital experiences.

AI accelerates the creation of immersive content, making it faster and more accessible. Scripts, melodies, 3D scenes, and characters can now be generated on the fly. Prototyping a game or series—and testing it—is faster and cheaper than ever.

Even NPCs (non-playable characters) are evolving. No longer static, they adapt their behavior and dialogue to players' actions. Game environments are generated dynamically, scene by scene.

✳ Toward Greater Inclusion

Immersive technologies break down barriers between virtual and physical realms, fostering digital inclusion. Work and social experiences will become more accessible, supporting greater participation from older adults and people with disabilities.

Haptic interfaces and AR overlays will help individuals with sensory impairments or cognitive decline. Shared workspaces will become more accessible to those with mobility issues.

Therapies will become more affordable and customizable through immersive platforms. Imagine petting a virtual animal and feeling it in your hand—all from home. Education will also benefit: adaptive, immersive learning will reduce reliance on costly physical infrastructure.

These technologies will bring new opportunities in education, work, and leisure. But they also raise questions: Could they encourage disconnection from the physical world? How will virtual spaces be regulated? Will we spend more time in virtual homes than real ones?

These technologies will bring new opportunities in education, work, and leisure.

TREND 3

WISE CITIES

Sustainability and Intelligence in Urban Futures

Experts agree: the true smart city of the future will combine cutting-edge technology with sustainable practices and empowered citizens. The foundation won't be concrete and asphalt alone, but a synergy of interconnected systems governed by collective intelligence.

Hyperconnected infrastructures will reshape urban life. Integrated networks will link everything from mobility to energy systems, making cities more efficient, sustainable, inclusive, and centered on human needs.

✱ Facing Climate Change

One of the most pressing threats cities face is climate change. With extreme weather events becoming more frequent and destructive, urban environments must become significantly more resilient.

Technologies like predictive analytics and IoT-based early warning systems will enhance emergency management. Urban resilience will hinge on two pillars: foresight and adaptability.

On one hand, combining satellite data with artificial intelligence will allow cities to forecast catastrophic events with unprecedented accuracy and lead time. On the other, connected infrastructure will respond in real time to protect citizens and urban systems.

But the city of the future will not only defend against climate change—it will also help mitigate it. Sustainability will go beyond reducing carbon footprints to include improving air quality, enhancing water management, and fostering biodiversity. Power grids will become smarter and support decentralized, sustainable energy production.

✱ Cities that Flow

The ability to anticipate and prevent problems won't be limited to climate resilience. It will also improve the flow and functionality of urban spaces, making cities more dynamic and livable.

Autonomous, connected mobility is already a reality in some places. Waymo operates robotaxi services across San Francisco, while UK-based Wayve is working to teach vehicles how to respond to unpredictable scenarios using embodied AI.

Mobility-as-a-Service (MaaS), as envisioned in *Megatrends 2023*, is beginning to take shape. Autonomous vehicles will eventually integrate seamlessly with public transport and infrastructure, enhancing real-time coordination and traffic flow.

✱ The Urban Future in Question

Many questions remain about what cities will become. How will 3D-printed buildings, smart materials, or advanced recycling systems reshape urban architecture? Could future cities serve as climate refuges? Will AI help decentralize economic activity and reduce reliance on megacities?

Cities of tomorrow will be shaped not only by technology, but by the choices we make today. Whether they become more inclusive, sustainable, and resilient will depend on our ability to integrate innovation with human values.

Technologies like predictive analytics and IoT-based early warning systems will enhance emergency management.

TREND 4

PRECI-SION MEDICINE

Tailoring Health for the Individual

Just a decade ago, sequencing a person's genome to guide cancer treatment seemed like science fiction. But it happened— and worked. A patient with a rare sarcoma was successfully treated with a drug developed for melanoma, all thanks to genetic insights.

Today, genome sequencing is faster, cheaper, and increasingly common. Genomics paved the way for personalized medicine, and now other disciplines are following its lead to shape the future of healthcare.

✱ Preventing, Not Just Treating

Precision medicine brings together genetics, proteomics, and synthetic biology to shift healthcare from a reactive to a proactive model—one tailored to the individual.

In Spain, researchers are already working on digital twins for cancer patients. These virtual models will allow doctors to anticipate disease progression, identify the most effective treatments, and adapt lifestyle interventions to improve outcomes.

Prevention becomes central in this approach. We now know that having a duplicated gene can lead to Alzheimer's. Identifying carriers early enables proactive, personalized interventions based on their genetic and lifestyle profiles.

This model could extend to many conditions, from diabetes to cardiovascular diseases. Pharmacogenetics will refine treatments to suit genetic variants, improving efficacy and reducing side effects—even predicting treatment responses before symptoms appear.

✱ Designing Life

Emerging technologies are pushing the boundaries of biological understanding. Large language models trained on biological data, neural networks predicting protein structures, and diffusion methods for molecular design are opening new frontiers.

These tools will unlock biology's full potential. They'll drive advances from tailor-made drugs to vaccines built on synthetic molecules, bypassing the limitations of natural biology.

Experts foresee a surge in AI-powered biological design that will revolutionize human health. Where once we tried to mimic nature—like radiation-resistant proteins or tissue regeneration—we will now design custom-built solutions to replicate or surpass these abilities.

N-of-1 therapeutics, quantum-assisted drug development, and engineered proteins for precise biological tasks are all on the horizon. The medicine of tomorrow will look nothing like what we know today.

✳ Protecting the Code

With increasingly individualized treatments, concerns about data privacy become more urgent.

More actors will be involved in designing therapies. This means collecting and managing more sensitive patient data.

Who owns the data from an N-of-1 trial—the patient, the hospital, the pharmaceutical company, or the tech provider? What laws govern its use? Who is responsible for its protection?

In an era of data-driven healthcare, robust security practices are essential. A breach won't just expose medical history—it could reveal a patient's genetic blueprint.

Vulnerability will take on new dimensions. So must our concept of digital security.

TREND 5

SPACE↗ TECHNOLOGY FOR EARTH'S FUTURE

Innovation Beyond Our Atmosphere

As predicted in *Megatrends 2024*, "many solutions to Earth's challenges will come from space." This insight is increasingly affirmed by experts. Advances in space exploration are becoming critical tools for addressing climate resilience, sustainable food production, healthcare, and the availability of energy and water.

Satellites already provide vast amounts of data to track environmental change, anticipate disasters, and guide policy decisions.

✱ What Space Does for Us

Space technologies are already solving immediate, terrestrial problems. Low-Earth orbit satellite constellations such as Starlink are bringing broadband Internet to remote regions. Data from the International Space Station is enhancing natural disaster forecasting. Satellite imaging supports precision agriculture and optimizes resource management at a global scale.

Looking ahead, initiatives are exploring how to beam solar power from space to Earth using microwave technology. These efforts aim to deliver clean, uninterrupted energy.

✱ More Eyes on Earth

High-altitude pseudo-satellites (HAPS) and compact observation satellites are pushing Earth monitoring to new heights. They offer high-resolution imagery that enables more accurate crop monitoring, improved logistics, and enhanced environmental management.

Spanish company Satlantis is one example of how private firms are innovating in this domain, offering cost-effective satellite solutions. These advancements promise more sustainable food systems and earlier wildfire detection. They also provide essential tools for climate adaptation and resilience.

Artificial intelligence is increasingly used to simulate environmental scenarios based on satellite data. These models are becoming crucial for disaster prevention and climate planning.

Looking ahead, initiatives are exploring how to beam solar power from space to Earth using microwave technology

✺ Beyond the Moonwalk

The momentum behind public and private space exploration is growing. SpaceX and China are planning missions to Mars before 2030. Spanish startup PLD Space is developing missions capable of transporting cargo and crew to the Moon by that same year.

But these missions aren't just about reaching new worlds. They are testbeds for technologies that could benefit life on Earth—such as energy generation, waste reuse, and resource management at unprecedented levels of efficiency.

Importantly, the space economy is becoming more democratized. Once the domain of national agencies, space is now open to a range of private actors. The trend is driven by innovation and cost reduction. For example, the cost of launching one kilogram into orbit has dropped from $15,000 in the early 2000s to around $4,000 today.

Reusable rockets, lighter satellites, and shared launch systems are making space more accessible and commercially viable.
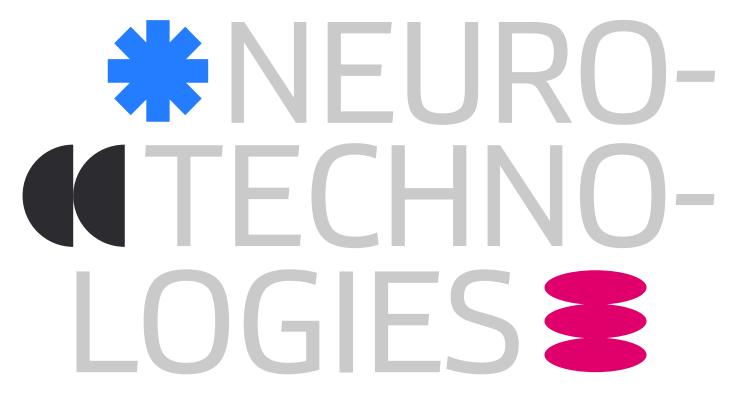
✺ Building a LEO Economy

The emergence of the Low Earth Orbit (LEO) economy is not just about launching new technologies, but managing existing ones. Space debris is a growing concern. As predicted in *Megatrends 2024*, "cleanup initiatives will become essential to mission success."

That future is now taking shape. ESA, in collaboration with OHB SE and ClearSpace, is preparing missions to retrieve satellites launched in the early 2000s. Spanish company GMV is testing nets to capture defunct objects.

These efforts are part of a broader orbital service economy. Services like satellite inspection, refueling, and deorbiting are already being commercialized by companies such as Japan's Astroscale.

Still, global governance will be essential. The growing number of countries and companies accessing space complicates regulation. But effective international frameworks are urgently needed to prevent space from becoming unsustainably congested.

The challenge is clear: to fully harness space for the benefit of humanity, we must ensure its responsible and sustainable use.

TREND 6

NEURO-TECHNO-LOGIES

Enhancing the Human Mind and Body

A paralyzed man navigates a virtual drone through an obstacle course using only his thoughts. Three people are already using Neuralink brain implants to design 3D objects or browse the Internet. Soon, these chips could control robotic arms or help rehabilitate stroke patients via mind-controlled exoskeletons.

Scenarios once confined to science fiction are rapidly becoming reality. Neurotechnology is moving from the extraordinary to the everyday.

✳ Unlocking Human Potential

Brain-machine interfaces (BMIs) are helping us overcome physical and cognitive limitations. They act as prosthetics for the mind—tools to help us navigate a demanding, tech-driven world.

As noted in *Megatrends 2024*, what is now being used to treat neurodegenerative diseases will also unlock new forms of interaction between humans and machines—and among humans themselves.

The same interfaces that help an ALS patient communicate with loved ones will soon support deeper, real-time collaboration with machines and people. These developments will be amplified by complementary technologies.

What new capabilities will emerge when neurotechnology merges with quantum computing? How will artificial intelligence and BMIs work together to transform cognition?

✳ Beyond the Implant

AI-powered tools will soon assist our decision-making and problem-solving processes, acting as cognitive partners integrated with our brain activity via BMIs.

Experts believe this partnership will significantly elevate human capability, enabling us to solve more complex problems with greater efficiency. It will also redefine how we connect emotionally and intellectually with others.

Technologies that decode internal dialogue with surprising accuracy are already here. The next step is transmitting those thoughts and emotions to others—ushering in a new era of human communication.

Increasingly non-invasive interfaces are accelerating this shift. Quantum sensors, for instance, are being tested to capture brain signals without the need for surgery. Companies like Meta and Apple are developing wearable devices capable of reading neural activity through the skin.

The use of neurotechnologies to connect people will open the door to a new era of human relationships.

✳ Security and Neuro-Rights

As these technologies become more integrated into daily life, the ethical and legal implications are growing more urgent.

Protecting BMIs from misuse is paramount. Thought reading, emotional influence, or behavior manipulation are no longer distant possibilities. Without safeguards, unauthorized access to brain data could have devastating consequences.

Experts argue for the development of robust ethical and legal frameworks to protect autonomy, mental privacy, cognitive freedom, and individual identity. These are the neuro-rights being debated globally— and already legislated in countries like Chile, Mexico, Brazil, and the United States.

Spain has also begun discussing neuro-rights in its national legislature. These frameworks must also address ownership and transparency of neural data, informed consent protocols, and equitable access to cognitive enhancement technologies.

Clicking "I agree" will take on new significance in a world where we are authorizing direct access to our minds.

Neurotechnology promises profound benefits. But to realize its potential, we must ensure it is ethical, secure, and inclusive.

TREND 7

SUSTAINABILITY FOR A GROWING WORLD

Innovation to Support a Thriving Planet

"Sustainability affects everything." *Megatrends 2024* highlighted how this concept has evolved—from a narrow focus on environmental protection to a broad, systemic principle shaping every aspect of life.

With a rising global population, sustainability must now embrace the complex interplay of energy, water, food, and materials. Balancing these pillars is essential to ensuring access to the resources we all need.

Advanced technologies in energy storage, biomanufacturing, and materials science are paving the way toward a more efficient and regenerative future.

✳ Waste with Value

The circular economy is a cornerstone of sustainable innovation. It focuses on maximizing resource use and minimizing waste—an imperative in a world of increasing scarcity.

This approach is already transforming entire sectors. From reclaiming degraded farmland to recovering critical raw materials for the digital and green transitions, it's the alliance between technology and environmental responsibility that is redefining efficiency.

Promising developments include near-total recovery of lithium and graphite from batteries, the use of recycled textiles in fashion, and the spread of regenerative agriculture to restore soil health.

✳ Biomanufacturing and Smart Materials

Biomanufacturing is taking sustainable production a step further. It's reshaping industries as diverse as food, fashion, construction, and electronics.

Quantum biosensors for precision agriculture, low-energy biocomputers, and lab-grown meat are just the beginning. These technologies allow for the creation of advanced products with minimal environmental impact.

In parallel, materials research is focused on reducing the use of virgin resources, water, and energy. AI-driven design enables the discovery of novel raw materials that are not only sustainable but also high-performing.

Soon, we won't need to extract these materials from nature—we'll instruct generative models to design and simulate them from scratch.

From reclaiming degraded farmland to recovering critical raw materials for the digital and green transitions, it's the alliance between technology and environmental responsibility that is redefining efficiency.

✳ Clean and Inexhaustible Energy

Abundant, clean energy is the backbone of a sustainable future. In many regions, the rise of "prosumers"—citizens who both produce and consume energy—is reshaping the energy landscape.

These decentralized networks will resemble an Internet of energy, allowing real-time exchange and optimization of electricity.

New storage solutions are also gaining traction. Some companies are turning skyscrapers into gravity-based energy reservoirs. Others are exploring the use of biofuels, green hydrogen, and advanced nuclear energy to support baseload demand.

Nuclear energy, in particular, is entering a new phase. Small modular reactors (SMRs) are being developed to power high-demand infrastructure, such as data centers. Microsoft, for instance, is considering reopening former nuclear facilities for this purpose.

Meanwhile, nuclear fusion—the holy grail of energy—remains decades away, but promising prototypes are already in development. Startups are working to make fusion commercially viable, offering a path to nearly limitless, emission-free power.

The future of nuclear energy will be the focus of the Bankinter Foundation's Future Trends Forum in June.

✳ Water and Food for All

Water management and food security are equally critical. Predictive analytics and smart irrigation are helping to optimize agricultural yields while minimizing resource consumption.

AI and IoT technologies are already enabling real-time water quality monitoring, infrastructure maintenance, and precise distribution. New systems are extracting water from air or recovering it more efficiently from waste.

Bioengineered crops that require less water—or that thrive in saline environments—have the potential to revolutionize agriculture in drought-prone areas. Satellite monitoring will allow farmers and authorities to take timely action before crops are lost.

These innovations will be essential in maintaining a stable food supply in the face of climate change and global population growth.

The path to sustainability is not a single solution but a convergence of technologies. It requires collaboration between sectors and a commitment to redesigning how we produce, consume, and share resources on a planetary scale.

TREND 8

INNO-
VATIVE
TALENT

Rethinking Education for a Technological Future

From "one-size-fits-all" to "this-fits-me." Technology is reshaping education, shifting it from a standardized model to one that is personalized, adaptive, and dynamic.

This transformation is already underway. Schools and universities are integrating immersive technologies and AI-driven platforms into learning environments. These innovations, alongside emerging tools like brain-machine interfaces (BMIs), will unlock tailored learning paths, flexible assessments, and deeper engagement. Yet, human-centered skills will remain essential.

✳ Optimizing the Learning Journey

The education of tomorrow aims to optimize each student's learning curve and develop the skills needed to thrive in a technological world. Advanced tools will personalize content and adjust to individual strengths and weaknesses in real time.

AI-powered virtual tutors are becoming more common, offering students immediate support and guidance. Large language models already help answer complex questions, guide problem-solving, and create interactive learning experiences.

Mixed reality environments are blending physical and digital worlds. Students might practice fitting a prosthetic on a virtual patient or test the structural resilience of a digital bridge—receiving instant, detailed feedback to apply later in real-world contexts.

Brain-machine interfaces will further enhance education by linking cognitive processes directly with digital platforms. This will create immersive and intuitive learning methods that are also more accessible. However, this evolution will raise important issues about student privacy, neuro-rights, and algorithmic bias.

✳ From Screen to Real Life

As *Megatrends 2024* asked: how will hyper-personalized learning affect essential human dimensions like empathy, debate, and critical reflection?

Technology alone isn't enough. The future of work will demand not just technical know-how but also emotional intelligence, communication, collaboration, and resilience. A renewed focus on learning-by-doing—combined with mentorship and real-world challenges—will help develop these capabilities.

In Africa, for example, hybrid platforms are combining online courses with community-based, project-driven learning. With guidance from peers and coaches, students build the confidence and mindset to succeed in informal labor markets or launch entrepreneurial projects.

AI enhances this process by providing 24/7 tutoring tailored to each learner's profile, offering personalized resources and challenges to build mastery over time.

✳ From Zombies to Explorers

Virtual tutors and AI copilots are not just supporting learners—they're training them for the digital collaboration that will define their future workplaces.

Students must learn not only how to consume knowledge but how to find, interpret, and act on it. The goal isn't to create passive "data zombies" who follow AI blindly, but active "explorers" who use digital tools to solve complex problems creatively and critically.

This means teaching students how to ask the right questions, evaluate sources, and make ethical, informed decisions. These human-centered skills are difficult to automate—and will remain the domain of teachers, mentors, and facilitators.

Educators will still play a central role in helping students grow, adapt, and flourish in a fast-changing world. The future of education lies in blending technological innovation with human guidance.

But big questions remain: What will credentials look like in this new system? Will AI tutors shape students' careers? Will learners form emotional bonds with them? And how will we ensure equal access to this new paradigm of education?

The education of the future will teach students to find the information they need and use the necessary tools to make the most of it.

TREND 9

THE NEW PARA-DIGMS OF DIGITAL SECURITY

If there is one domain that must evolve as rapidly as technological innovation itself, it is digital security. As cyber threats grow more sophisticated, the need for resilient and forward-looking protections becomes more urgent.

Beyond the looming quantum threat to current encryption systems, digital security must now contend with the risks posed by brain-machine interfaces, immersive virtual environments, and the proliferation of generative AI tools.

✳ A More Complex Digital World

As our physical and virtual lives become increasingly intertwined, the digital landscape grows more complex—and more vulnerable.

New access points, devices, and interfaces are opening up previously unimagined vectors for attack. Brain-machine interfaces and immersive environments blur the line between internal and external experiences, raising new questions around identity, autonomy, and personal data.

Before these technologies become mainstream, foundational issues like privacy, security, and digital identity must be addressed.

✳ Securing the Digital Mind

The fusion of BMIs with digital platforms creates the need for new security protocols. If thoughts, emotions, or actions can be read—or influenced—they must be protected from unauthorized access and manipulation.

Quantum key distribution (QKD) technologies are being developed to secure communication channels by instantly detecting intrusions. These quantum tools could eventually safeguard neural data, ensuring that only authorized recipients can access sensitive information.

BMIs, as part of more complex interconnected systems, will also be vulnerable to quantum computing attacks. Crypto-agility—the ability to update encryption algorithms quickly as they become obsolete—will be crucial in the post-quantum era.

Experts are also exploring "quantum digital fortresses": multilayered security infrastructures designed to evolve alongside emerging threats, ensuring that each layer of protection can adapt as new vulnerabilities arise.

New access points, devices, and interfaces are opening up previously unimagined vectors for attack.

✱ Empowering the User

As digital interactions deepen, users will need to play a more active role in protecting their own information—especially when granting access to thoughts or biometric data.

Decentralized identity solutions based on blockchain can give users control over their digital personas. These systems allow individuals to choose which data to share, with whom, and under what conditions. Data becomes portable, tamper-resistant, and transparent.

By eliminating reliance on centralized intermediaries, decentralized identity also reduces the risk of massive data breaches.

✱ When AI Fakes Reality

Generative AI poses a separate set of threats. As tools become more accessible, the spread of deepfakes, identity fraud, and synthetic media manipulation becomes more difficult to control.

AI will need to defend against its own misuse. Machine learning and forensic algorithms are already being trained to detect deepfakes and verify digital content. But these tools must become faster, more accurate, and deployable in real time.

The arms race between detection and deception is underway. Robust tools, combined with proactive governance, will be essential.

✱ A New Framework for Prevention

Technology alone won't be enough. Digital literacy and early education are essential to helping individuals navigate risks and recognize manipulation.

Citizens remain the most vulnerable entry point for many attacks. Building awareness is a key defense mechanism.

At the same time, regulation must evolve. Global standards and legal frameworks will be needed to define acceptable practices, ensure accountability, and create shared responsibilities among governments, companies, and users.

In a world where threats evolve at the speed of innovation, digital security must become more anticipatory, adaptive, and aligned with human values.

TREND 10

QUANTUM
BREAKTHROUGHS

Unlocking Industry Transformation through Next-Generation Computing

The steam engine powered the Industrial Revolution. But it wasn't the first of its kind. Spanish inventor Jerónimo de Ayanz patented a similar design over a century earlier. Why did Watt's version succeed? Because it found the right partner in industrialist Matthew Boulton, who saw its practical potential.

The history of technology teaches us that the tipping point comes when science becomes application. Quantum technologies are now approaching that threshold.

Experts don't expect a sudden "ChatGPT moment" for quantum computing. Instead, they anticipate incremental but powerful advances that gradually demonstrate quantum's transformative capabilities.

✳ Classical Computing Meets Quantum Data

One early example of quantum's impact is the rise of large-scale quantitative models (LQMs). Unlike LLMs, which generate natural language, LQMs are designed to process and produce complex scientific, technical, and financial data.

These systems rely on classical computing but are guided by the logic of quantum mechanics. They simulate phenomena in physics, chemistry, biology, and finance with high precision, producing synthetic data to solve real-world problems.

LQMs are already being tested in various sectors. An Alphabet spin-off is using them to interpret Earth's magnetic signals for navigation. Other applications include drug discovery, materials science, climate modeling, and financial forecasting.

These tools offer a glimpse into the kind of innovation quantum-driven systems will make possible.

✳ Realism Over Hype

For quantum technologies to reach industry at scale, progress must be grounded in realism. Major challenges remain: quantum software development, error correction, and building chips that can handle high qubit counts without instability.

Combining quantum computing with AI and quantum sensors has the potential to exponentially accelerate innovation. But the real challenge lies in moving from lab experiments to scalable, dependable applications.

Some early opportunities are already being explored in industries like automotive (new battery design) and energy (optimization of grid systems). Hybrid computing—where classical and quantum machines work together—is accelerating these efforts.

LQMs are already being tested in various sectors. An Alphabet spin-off is using them to interpret Earth's magnetic signals for navigation.

✷ Accelerators in Action

Quantum computing can shorten the drug development lifecycle by simulating molecule interactions with greater precision. This could streamline clinical trials by improving candidate selection and reducing failure rates.

Other sectors, such as climatology and cybersecurity, will benefit from quantum's ability to simulate and forecast highly complex scenarios.

As *Megatrends 2024* noted, hybrid systems are already helping discover the next generation of electric vehicle batteries. This interplay between quantum and classical computing will continue to be a major driver of adoption.

✷ Building Toward Scale

Several key breakthroughs are advancing quantum computing toward industrial viability. Google's Willow chip, for example, improves error correction as it scales. The system becomes more quantum as more qubits are added.

Microsoft has made strides in entangling logical qubits—more stable and reliable than physical ones—and achieved this ahead of schedule. IBM, meanwhile, has connected separate quantum chips to work in tandem for the first time.

Yet scaling quantum technology is not just a technical challenge—it's a human one. We need software developers trained to program quantum systems, as well as hardware experts and regulatory clarity.

Industry and education must evolve in tandem to meet demand. Without skilled talent, even the most powerful technology risks going underused.

✷ The Role of Semiconductors

Semiconductors remain essential to the evolution of both classical and quantum computing. As demand surges, new generations of semiconductors—and entirely new architectures—may be required to unlock the full potential of quantum systems.

Global supply chains, national strategies, and startup innovation will all influence how fast and how broadly these technologies can scale.

The big question: Will current semiconductor innovations be enough to support widespread quantum adoption—or will we need to imagine computing architectures that don't yet exist? Whether tomorrow is better than today will depend on how well we build it—starting now.

EDITORIAL

2025
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Scientific and technological innovation often enters our lives quietly. Without much fanfare, we find ourselves living in scenarios that once belonged only to science fiction.

Megatrends 2025 captures this reality. Genome sequencing is already used to personalize treatments. People are controlling devices with their minds. Robots are performing surgeries. These are no longer distant visions—they are today's breakthroughs.

As *Megatrends 2024* warned, the future is being built at an accelerating pace. Thanks to these advances, we now collaborate with autonomous agents and robots that adapt to their environments and make decisions. We are forging stronger connections between humans and machines through neurotechnology. And we are beginning to inhabit secure, immersive digital spaces.

Learning is evolving through direct brain-computer interaction. Cities are becoming predictive, capable of anticipating climate events and managing urban flows. The food and energy systems that support us are being reimagined through biotechnology and artificial intelligence.

Startups are helping clean up space. AI is designing new materials to preserve resources. Sustainability is no longer a distant goal—it's a fast-moving frontier driven by innovation.

The future ahead is undeniably exciting. But so is the present. It is now, in today's decisions and developments, that we are laying the foundation for the world to come.

Whether tomorrow is better than today will depend on how well we build it—starting now.

Neurotechnology will enable a deeper connection with others and open the door to an era of greater connection between people and machines

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