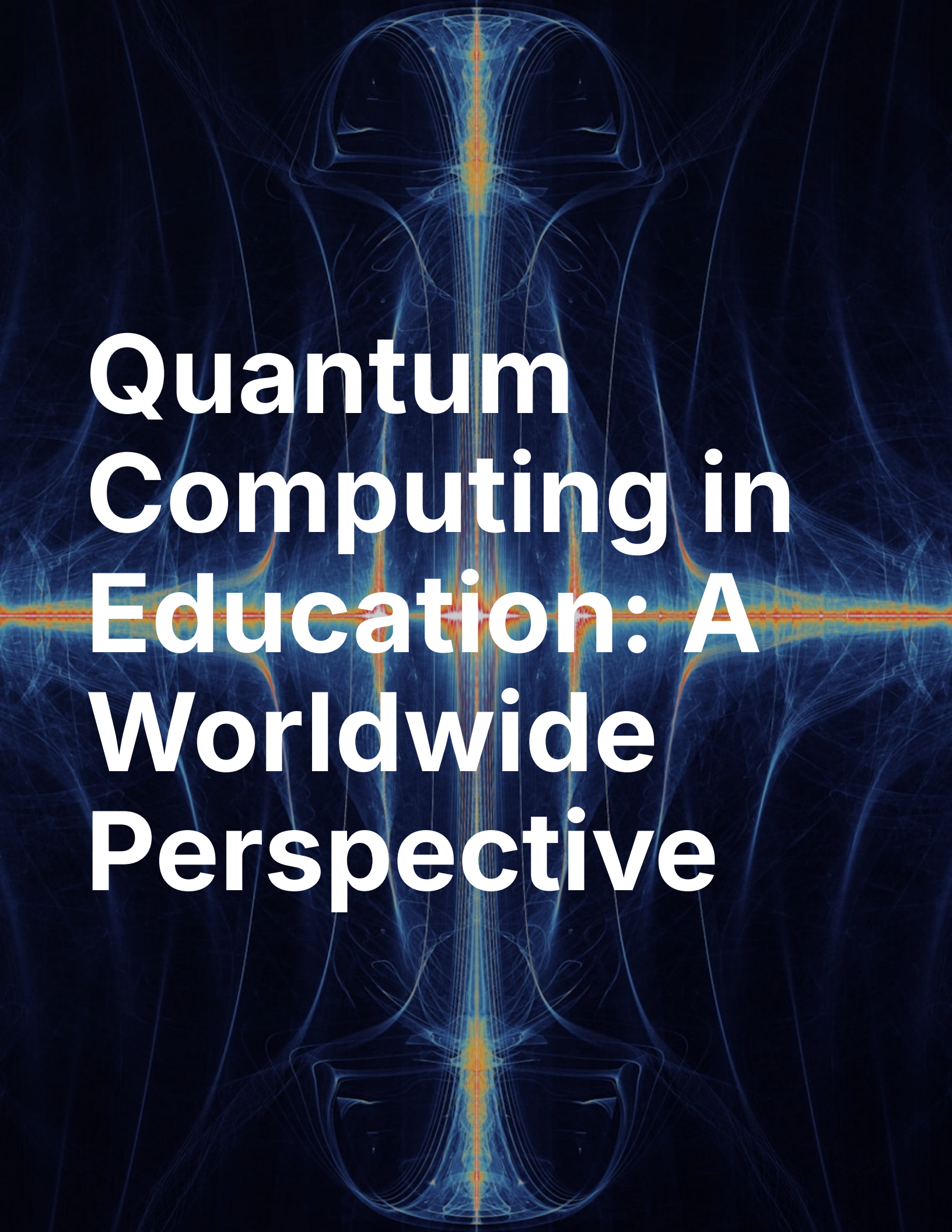


The background features a dark blue field with a faint, glowing silhouette of a human figure. Overlaid on this are intricate, web-like patterns of light blue and orange-yellow lines, resembling neural connections or quantum pathways. A prominent horizontal band of orange and yellow light crosses the center of the image, passing behind the text.

Quantum Computing in Education: A Worldwide Perspective

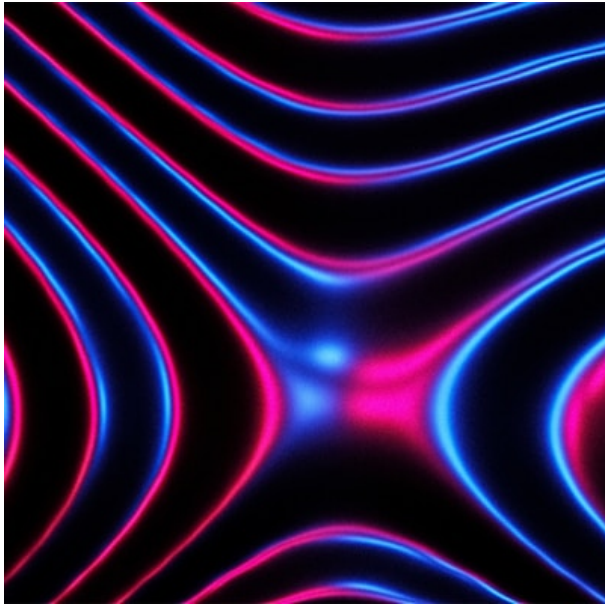
Executive Summary

Applying quantum computing to education involves using quantum technologies to enhance how we teach, learn, plan, and understand education itself. It shifts the focus from training the next generation of quantum scientists to leveraging quantum capabilities to develop smarter, more inclusive, and efficient educational systems. This change can transform the entire learning ecosystem, not only through improved tools but also by adopting entirely new perspectives on knowledge, education, and human potential.

Modeling Complex Learning Systems

Simulating complex systems with many interacting variables is a strength of quantum computers. This capability could be applied in education to model how students learn, imitate cognitive processes, or understand how learning disabilities (like autism, dyslexia, or ADHD) affect the acquisition and retention of knowledge. These simulations could lead to the development of neurodiverse-friendly tools, more personalized interventions, and better predictions of learning outcomes. Education researchers might also use quantum simulation to evaluate the effects of policy changes or curriculum adjustments before applying them broadly.

Personalized Learning Paths



Personalized learning is becoming increasingly important, but it requires processing large amounts of data on students' behavior, progress, preferences, and learning styles. Traditional algorithms can only handle so much complexity. Quantum-enhanced machine learning has the potential to improve real-time content adaptation, enabling educators or educational software to deliver highly personalized instruction. Furthermore, quantum models could assist in creating tailored remediation plans and strengthening early warning

systems that identify students at risk of falling behind or dropping out.

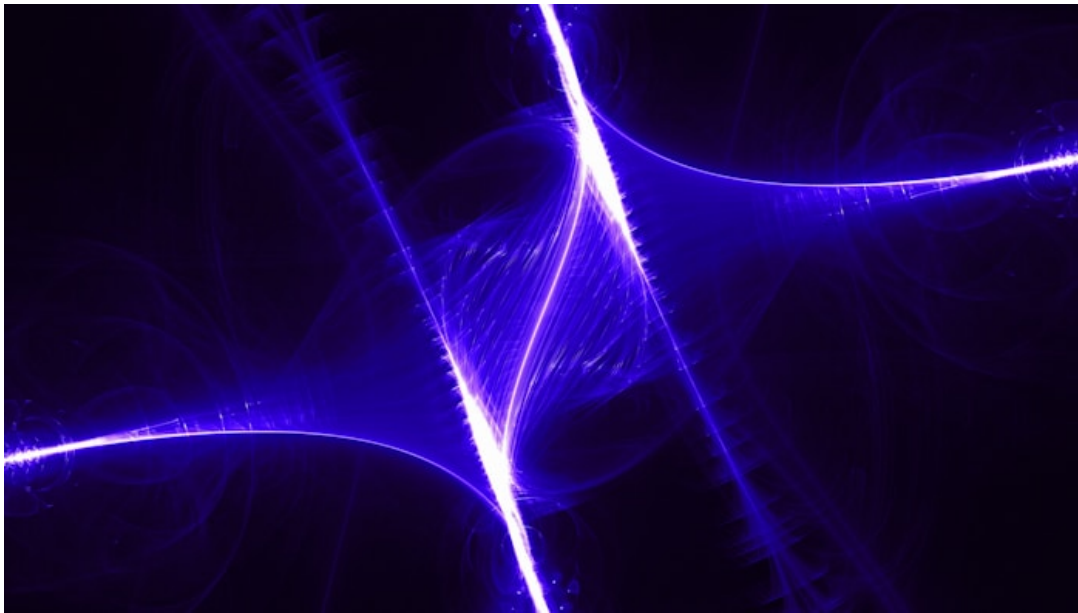
Solving Education Logistics Problems

Course scheduling, classroom assignments, teacher deployment, and curriculum sequencing are just some of the major logistical challenges faced by large educational systems. These issues often fall under the category known as combinatorial optimization, which quantum computers are especially well-equipped to handle. For example, a quantum algorithm could quickly identify the most effective way to allocate thousands of classes across a university, minimizing conflicts and increasing accessibility. Additionally, it could optimize the distribution of human and physical resources among school districts, especially in underserved or high-demand areas.

Supporting Scientific Research in Pedagogy

Quantum computing could speed up data-heavy education research, enabling faster and more advanced analysis of large educational datasets. This includes meta-analyses, modeling how pedagogical innovations spread and work, analyzing teaching practices, or simulating various policy interventions across different regions and populations. Quantum-powered simulations could, for example, explore the long-term impacts of early childhood education on societal outcomes or identify the best approaches for improving STEM access and equity.

Understanding Learning at a Fundamental Level



On a more theoretical and speculative level, scientists are exploring potential connections between human cognition and quantum information theory, which raises the question of whether quantum models could be useful. However, there is still much to discover about memory, conceptual understanding, and decision-making under uncertainty. New frameworks for instructional design or even theories of how people learn based on quantum mechanics could emerge from this.

Strategic Implications

As the field progresses, the education sector may become both a beneficiary and a contributor to quantum innovation. Exploring pilot programs and research collaborations could give early adopters—such as academic institutions, education ministries, and edtech startups—a competitive advantage. However, morality and fairness will be crucial factors. To avoid widening existing digital or cognitive divides, access to quantum-enhanced educational resources must be carefully managed.

Real-World Use Cases

Optimizing University Course Scheduling



Quantagonia & MathPlan: This is a clear example of a company applying quantum-classical computing to a real-world educational challenge. The software firm Quantagonia has partnered with MathPlan, a leader in automated class and room scheduling for universities. Their aim is to use hybrid algorithms to enhance the speed and efficiency of producing optimal schedules, which is a classic combinatorial optimization problem. This example is a perfect case study for the report's section on Solving Education Logistics Problems.

Research & Academia: Several research papers (from institutions like Pusan National University and others) have investigated using quantum-inspired algorithms and hybrid methods to address the job shop scheduling problem, a type of optimization that is directly comparable to class scheduling.

Trialling Quantum in Ed-Tech

Although a real-time, personalized learning platform powered by quantum technology for the general student body is still a ways off, ed-tech businesses and research labs are laying the foundation

Qureca: This ed-tech company is developing a learning management system that offers **personalized learning paths**. Although they are not using a full quantum computer, they are building the algorithmic frameworks and infrastructure needed for a future quantum upgrade. Their platform is already implementing the immediate-term, classical version of the quantum-enhanced vision, using AI and machine learning to create personalized learning paths.

Intelligent Teaching Assistants: A paper published on arXiv describes a system that uses a knowledge graph to enhance a **Large Language Model (LLM)** for context-aware tutoring. This step is essential in advancing quantum-enhanced machine learning for education. Although the system is classical, it aims to address two major issues with current AI: long-term planning and context. Quantum AI is designed to help with these specific challenges. This sets the foundation for future quantum integration.



Opportunities



Reimagining the Learning Ecosystem

Quantum computing calls for education to move from incremental improvements to a complete overhaul. It provides not only superior tools but also entirely new ways of understanding how people learn, interact, and develop.

Modeling Complex Learning Systems

Quantum simulations can **map the cognitive landscape** more precisely than classical tools. Think: understanding how ADHD, dyslexia, or autism interact with different learning methods — not just on the surface but deep within the structure of cognition.

Instead of being one-size-fits-all or retrofitted, these models could guide customized interventions that are genuinely inclusive.



Hyper-Personalized Learning Paths

Quantum-enhanced machine learning could **adapt content in real time**, like a tutor who truly “gets” you—your pace, your struggles, and your sparks of curiosity.

Early warning systems could be significantly enhanced, enabling teachers to **intervene before a student falls behind**, not after.



Solving Logistical Gridlock

Quantum algorithms thrive in **combinatorial chaos**, making them perfect for solving puzzles like course scheduling, resource allocation, and curriculum sequencing.

This could **democratize access** by efficiently distributing resources in underfunded or overcrowded districts.



Accelerating Pedagogical Research

Quantum computing could process large datasets quickly, enabling faster **research iterations** in education and more detailed evaluations of teaching methods and policies.

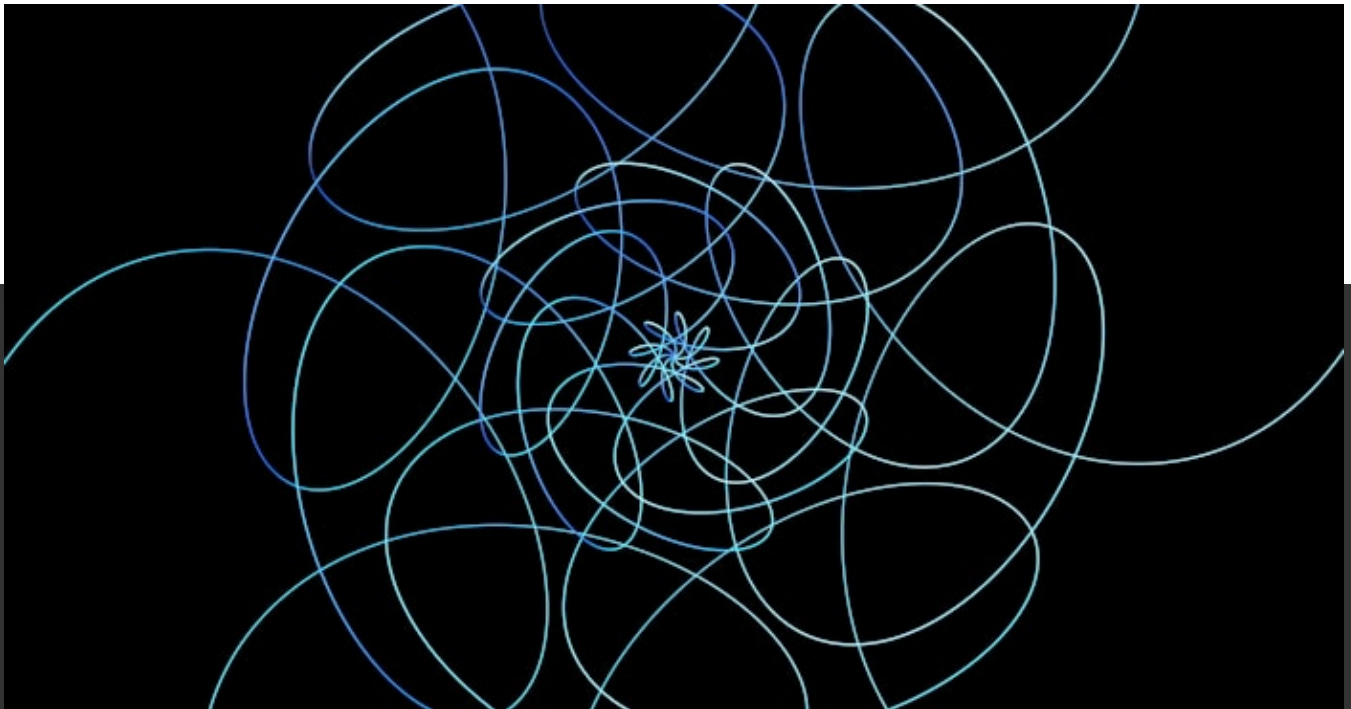




Exploring Learning at a Quantum Level

Even if still speculative, exploring quantum cognition could inspire **quantum-inspired teaching methods**—completely new approaches to understanding memory, decision-making, and learning amidst uncertainty.

Strategic Leverage for Early Adopters



Institutions that invest early (universities, ministries of education, and edtech startups) can secure **first-mover advantages**, influencing the future of the quantum education field.

Challenges

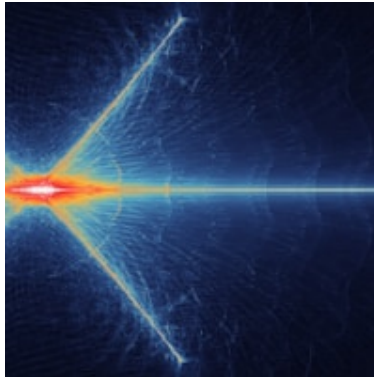
Access and Equity

If only elite institutions or wealthy countries have access to quantum-enhanced tools, the **digital divide becomes a quantum gap that is chasm-like.**

There's a real risk of **increasing cognitive inequalities**, especially if neurodiverse or underserved students are excluded from the main loop.



Ethical Complexity



Quantum systems process large amounts of data—raising concerns about **privacy, bias, surveillance**, and consent, especially when working with vulnerable student populations.

Predictive models could unintentionally lead to **algorithmic determinism** (e.g., labeling students as “at risk” in ways that follow them like shadows).

The Readiness Gap

Most educators, school systems, and policymakers are **nowhere near ready** to integrate quantum tools. Training, infrastructure, and digital literacy all lag far behind.

Without strategic planning, the sector risks being **overwhelmed by complexity** or distracted by hype.

Fragile Infrastructure

Quantum computers remain experimental, fragile, and very costly. Using them for essential educational processes is currently **impractical on a large scale**

Widespread adoption will likely require **hybrid systems** and significant upgrades to cloud infrastructure.

Uncertain Theoretical Foundations



Some of the most exciting prospects—such as quantum-inspired models of cognition—are still primarily **speculative**. This creates a philosophical and scientific frontier but also poses a credibility risk.

The field could suffer from **over-promising and under-delivering**, especially if marketing gets ahead of science.

Policy & Governance Lags

Quantum innovations are outpacing policy. There's little in place to guide **ethical use, data governance, or equitable deployment** across diverse educational contexts.

Global Outlook

The main improvement is shifting from a one-size-fits-all approach to highly personalized learning and better resource management. Quantum-enhanced systems will offer new tools for educators and administrators. This will lead to:

Personalized Learning Paths: AI and quantum-enhanced models will analyze individual learning styles and progress in real-time, adapting content and providing customized remediation.

Logistical Optimization: Resolving complex logistical problems such as course scheduling, classroom assignments, and teacher deployment in large school districts, while ensuring resources are distributed fairly and efficiently.

Deeper Insight into Cognition: Quantum-inspired models could offer new perspectives on how humans learn and process information, leading to more effective teaching methods.



The Quantum- Enabled Personalized Learning Loop

Imagine a student struggling with a particular physics topic. Here's how a quantum-enhanced system could develop a personalized learning path for them.

Step 1: Ingesting the Data (The "What")

A hybrid quantum-classical system first ingests a rich, multidimensional dataset about a learning journey. This goes beyond simple test scores and includes:

Performance Metrics: Grades on quizzes and homework, time spent on each question, and specific patterns of incorrect answers.

Behavioral Data: How often a student re-watches a video, which practice problems they skip, and their overall progress pace.

Cognitive & Emotional Data: Inferred data (from eye-tracking or an emotion estimation system, with proper consent) to understand when the student is engaged, distracted, or frustrated.



Step 2: The Quantum Engine (The "How")



The classical component handles the initial data sorting, while the most complex task—identifying the best learning path—is delegated to the quantum algorithm.

Instead of trying to identify the single best next step among thousands of possibilities (a task that is computationally hard for a classical computer), the quantum algorithm considers all potential learning paths at once. It's like finding the perfect route through a vast, changing city where every turn impacts all other possible turns.

The algorithm factors in:

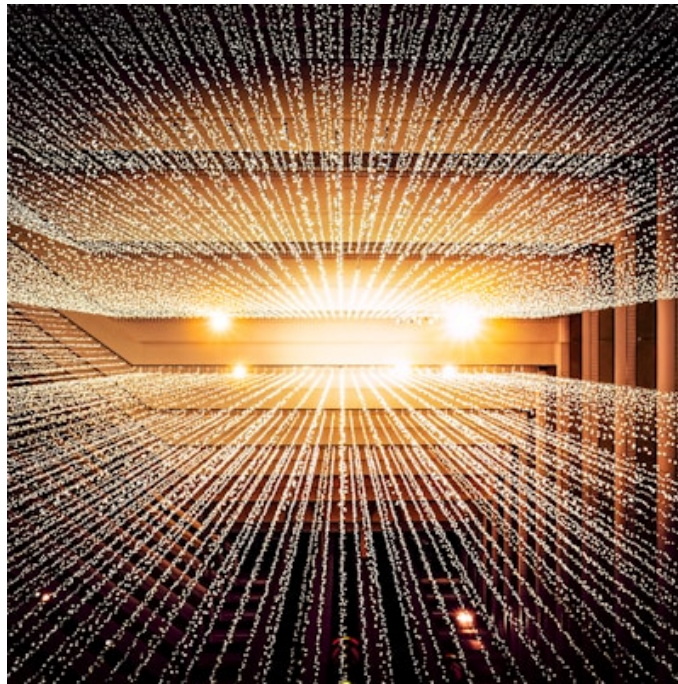
The student's current knowledge gaps.

The connections between concepts that the student needs to learn.

The student's optimal learning pace and style are also taken into consideration.

The goal is to maximize both knowledge retention and engagement.

Step 3: Generating the Output ("What it Looks Like")



Within seconds, the algorithm delivers a highly targeted, actionable output to the educator. This isn't just a generic suggestion but a detailed, personalized learning plan, which could look like:

A prioritized list of 3-5 micro-lessons that are tailored to address unique error patterns specifically.

A recommendation for a specific content format (e.g., This student will benefit most from a 90-second animated video on vector addition before attempting a quiz).

An optimized problem set composed of exercises that focus on a specific, foundational concept they are having difficulty with, rather than a random collection of problems

The educator can intervene proactively by using a visual learning map that displays the students' progress and identifies potential future roadblocks.

Step 4: The Educator's Role (Putting it into Action)

The quantum system doesn't replace the educator; it empowers them. The educator uses this output to:

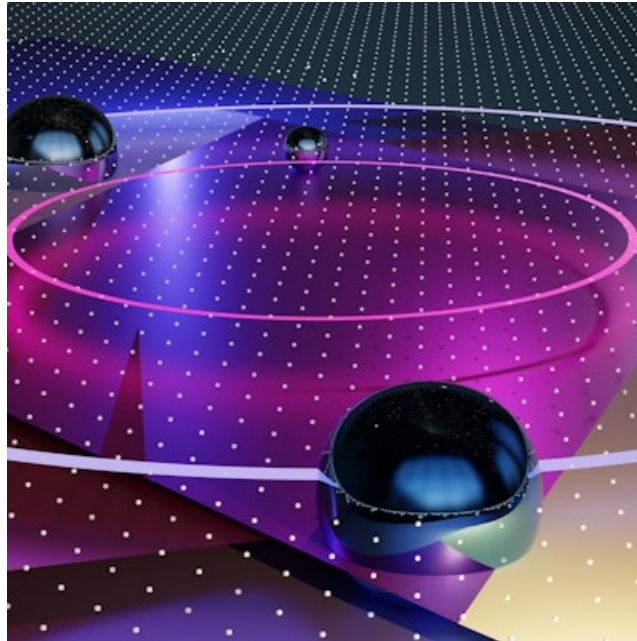
Guide instruction: They can instantly provide a targeted explanation or resource during a one-on-one session, knowing exactly where the student's a-ha moment is.

Save time: They are freed from the tedious, time-consuming task of manually analyzing data for each student.

Intervene proactively: The system gives them the insights to reach students at risk of falling behind before they even realize they're in trouble, fundamentally changing the nature of teaching from a reactive to a proactive profession.



Quantum computing in education is still in its early stages worldwide, but the momentum is rapidly increasing. The focus is shifting from “quantum science only” to integrating quantum into policy, workforce development, education curricula, infrastructure, and international partnerships. Key areas being addressed include:



Quantum literacy / quantum workforce training (in universities, sometimes even in K–12).

Building policy and funding frameworks that explicitly include quantum technologies and education.

Infrastructure includes simulation tools, labs, quantum research centers, and quantum hardware.

International alliances and cooperation to exchange standards, co-research, best practices, and ethical and legal frameworks.

Emphasis on inclusion and equity, particularly in historically underresourced areas.

Countries are realizing that if they want to be economically competitive, participate meaningfully in next-generation technology, be leaders in science, etc., quantum education is no longer optional.

Leading Countries & Regions

China: Has one of the most significant public investments globally (~US\$15B) in quantum tech. National plans include provisions for education and workforce development, such as the Education Modernization 2035 plan, which includes preparing the next generation for quantum technology.

European Union: In July 2025, the European Union unveiled a quantum strategy that prioritized research and innovation, infrastructure strengthening, ecosystem development, and dual-use/spin-off technology. QuantERA, the Flagship of Quantum Technologies, etc.

UK: The UK has a National Quantum Strategy (2023) with goals out to 2034; multiple quantum tech hubs; doctoral training programs; labs; and bridging academic, commercial, and policy sectors.



India: The National Quantum Mission (approved 2023–2031) has been funded, technical groups (TGs) and thematic hubs (T-Hubs) have been established, infrastructure and labs have been planned, and workforce development and education have been prioritized.

Nordic Countries (Denmark, Finland, Sweden, Norway, etc.)
A coordinated Nordic-level strategy was announced for quantum technologies, including talent development, infrastructure, shared regulatory and commercialization goals.



UAE: Via the Technology Innovation Institute in Abu Dhabi, a quantum research centre is being established, aiming to develop quantum algorithms, communications etc

Gaps, Trends & Countries Working Their Way There



Latin America is still in the early stages. For example, in **Colombia**, there are efforts to introduce quantum computing into higher education and align with international competence frameworks, but infrastructure and funding remain limited.

Some countries lack formal national policies but are still participating through research, academic initiatives, or inclusion in international quantum networks.

There's growing focus on *quantum literacy*: not just training quantum physicists, but providing broader student populations with frameworks to understand, utilize, or at least critically engage with quantum technology.

Ethical, policy, and regulatory frameworks are struggling to keep pace. Many countries are still in the process of defining data governance, privacy, and equity in the context of quantum education.

Global Outlook: Where Quantum Education Is Headed



The global education sector is poised to adopt quantum technologies in the coming years, not only for research purposes but also as a fundamental component of national strategies. Formal policies and investments to integrate quantum computing into education systems are already being advanced by nations like China, India, the United Kingdom, and EU members.

A significant rise in **public-private partnerships** is expected, as educational institutions increasingly collaborate with industry leaders to develop hardware, software, simulation environments, and practical applications for quantum learning.

To support this evolution, the **standardization of quantum-related skills and competencies** will become essential—defining what it means to be “quantum-literate” across different educational levels and professional domains.

Finally, **global cooperation and competition** will both intensify, with nations seeking to secure their place in the emerging quantum landscape by investing in talent development, infrastructure, and innovation ecosystems.

This moment represents not only a technological shift but a strategic one—redefining how the world prepares learners for a future shaped by quantum possibility.

