

## 1. Problem Statement

Traditional educational platforms lack intelligent personalization, real-time engagement, and meaningful gamification. Students face fragmented learning experiences with static quizzes, no social interaction, and minimal feedback on performance. Teachers struggle with manual quiz creation and lack tools for live, interactive sessions.

**Our Solution:** An AI-powered microservices platform that transforms learning through intelligent quiz generation, real-time multiplayer sessions, comprehensive gamification, and video collaboration — all unified under one seamless experience.

## 2. Approach & AI Components

### 2.1 AI-Powered Quiz Generation

Leveraging **Google Gemini AI** for intelligent content creation. Teachers input a topic or upload documents (PDF/DOCX/TXT), and our system generates contextually relevant, difficulty-calibrated questions with explanations.

- **Topic-Based Generation:** Natural language topic → structured quiz with multiple difficulty levels
- **Document Parsing:** Extract key concepts from uploaded materials using PDF.js and Mammoth.js
- **Adaptive Difficulty:** AI adjusts question complexity based on user performance history

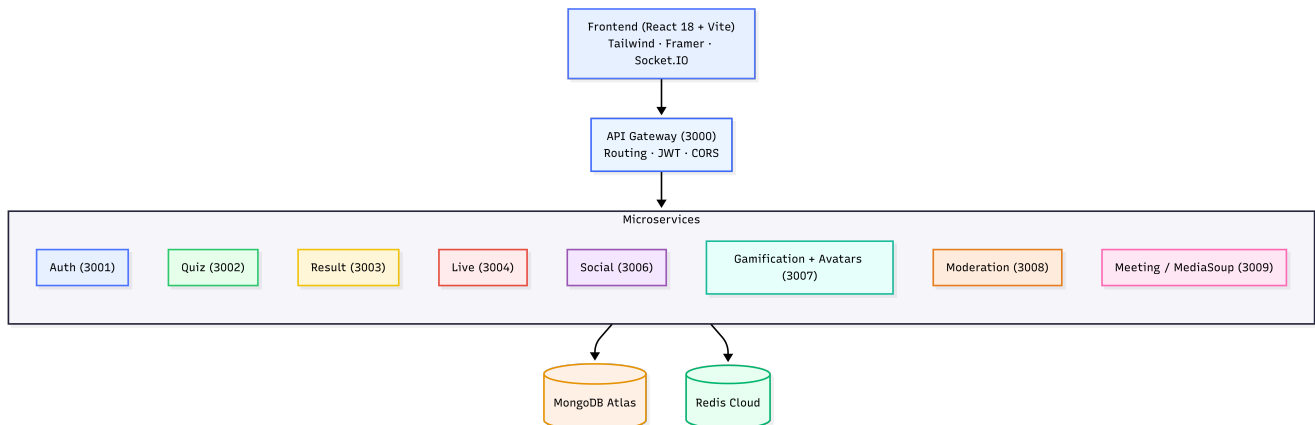
### 2.2 AI Study Buddy

An intelligent tutoring assistant that provides real-time explanations, study tips, and personalized guidance. Uses conversational AI to answer student queries contextually.

### 2.3 Smart Analytics

- Performance pattern recognition for strength/weakness analysis
- Personalized quiz recommendations based on learning gaps
- Predictive insights for optimal study scheduling

## 3. Technical Architecture



### 3.1 Microservices (9 Services)

Service	Port	Function
API Gateway	3000	Routing, Auth, Rate Limit
Auth	3001	JWT, OAuth, Roles
Quiz	3002	CRUD, AI Generation
Result	3003	Analytics, Leaderboards

Service	Port	Function
Live	3004	Real-time, Duels
Social	3006	Friends, Chat
Gamification	3007	XP, Achievements, Avatars
Moderation	3008	Content Safety, Reports
Meeting	3009	Video (MediaSoup)

### 3.2 Technology Stack

React 18	Node.js 20	MongoDB Atlas	Redis Cloud	Google Gemini AI	Express.js	Socket.IO	MediaSoup SFU	TailwindCSS	Framer Motion
Bull Queues	JWT Auth								

⚠️ 4. Challenges & Mitigations

Challenge	Impact	Mitigation
Real-time Synchronization	Live quizzes require sub-100ms latency for fair competition	Socket.IO with Redis pub/sub for cross-instance sync; optimistic UI updates
AI Response Quality	Generated questions may have errors or poor formatting	Structured prompts with validation; teacher review workflow; feedback loop
Video Scalability	WebRTC mesh fails beyond 4-5 participants	MediaSoup SFU architecture with multi-worker support; TURN fallback
Database Performance	Complex analytics queries slow down with scale	Redis caching layer; pre-computed aggregations; indexed queries
Microservices Complexity	Distributed system debugging and consistency	Centralized logging (Winston); shared error handling; Bull job queues
NAT Traversal (WebRTC)	Users behind strict NATs can't establish connections	STUN servers (Google); TURN relay configuration; announced IP setup

🚀 5. Roadmap to Final Build

Phase 1 ✓	<b>Core Platform (Completed)</b> Microservices architecture, Auth, Quiz CRUD, AI generation, Result analytics, Basic gamification
Phase 2 ✓	<b>Real-time Features (Completed)</b> Live quiz sessions, 1v1 duels, Socket.IO integration, Leaderboards, Social features
Phase 3 ✓	<b>Video Conferencing (Completed)</b> MediaSoup SFU implementation, Multi-participant rooms, Screen sharing, In-meeting chat
Phase 4	<b>Advanced AI (In Progress)</b> Adaptive difficulty engine, Personalized learning paths, Performance predictions, Voice-based questions
Phase 5	<b>Mobile &amp; Polish (Planned)</b> Flutter mobile app, Push notifications, Offline mode, Performance optimization, Accessibility

🌐 6. Deployment

Frontend:	<a href="https://cognito-learning-hub.vercel.app">https://cognito-learning-hub.vercel.app</a>
API Gateway:	<a href="https://api-gateway-kzo9.onrender.com">https://api-gateway-kzo9.onrender.com</a>
GitHub:	<a href="https://github.com/amitesh-7/Cognito_Learning_Hub">https://github.com/amitesh-7/Cognito_Learning_Hub</a>

🌟 7. Key Differentiators

<ul style="list-style-type: none"><li>• <b>AI-First Design:</b> Not an afterthought — AI powers core functionality</li><li>• <b>True Microservices:</b> 9 independent, scalable services</li><li>• <b>Real Gamification:</b> 15+ achievements, 50 levels, quests, streaks</li></ul>	<ul style="list-style-type: none"><li>• <b>Production-Ready:</b> Redis caching, job queues, error handling</li><li>• <b>Video at Scale:</b> MediaSoup SFU, not peer-to-peer mesh</li><li>• <b>Modern UX:</b> Glassmorphism, smooth animations, responsive</li></ul>
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👥 8. Team

<p><b>Team OPTIMISTIC MUTANT CODERS</b> — Passionate developers building the future of education technology. Combining expertise in AI, distributed systems, and user experience to create an impactful learning platform.</p> <ul style="list-style-type: none"><li>• Amitesh Vishwakarma (amitesh-7)</li><li>• Rakshita (neely941565-ops)</li><li>• Priyanshu Chaurasia (priyanshu-1006)</li><li>• Ritesh (riteshydv05)</li></ul>
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