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EquiLab: Real-Time Paper Trading Platform for Financial Education and Risk-Free Strategy Validation

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Abstract—*EquiLab is a web-based paper trading platform designed to simulate the complexities of the stock market in a risk-free environment. Modern financial markets are characterized by high volatility, which often serves as a barrier to entry for novice investors due to the psychological and financial impact of potential losses . EquiLab addresses this challenge by providing a high-fidelity simulation using virtual capital, allowing users to execute market orders, manage diversified portfolios, and analyze performance metrics without real-world financial exposure . To address these barriers, the project titled EquiLab is a web-based paper trading platform designed to help users learn and practice stock trading in a safe, risk-free environment. The system simulates real-world trading operations such as buying and selling stocks using virtual funds, while providing features like secure login authentication, portfolio management, and automated profit/loss tracking. Built on a robust MERN (MongoDB, Express.js, React, Node.js) stack and utilizing Next.js for optimized performance, the system incorporates real-time market data handling and a double-entry ledger system to ensure transactional integrity. This paper details the system architecture, the implementation of complex analytical tools like Sharpe ratio calculation and sector exposure tracking, and a comparative analysis against existing financial simulation tools.*

Index Terms— *Financial literacy, paper trading, MERN stack, portfolio analytics, real-time simulation, stock market education, double-entry ledger.*

I. INTRODUCTION

The democratization of financial markets through digital platforms has led to a surge in retail participation. However, the transition from theoretical knowledge to practical execution remains a significant hurdle for beginners. Traditional educational methods often fail to capture the real-time pressure and technical nuances of active trading, while live trading environments impose a high "tuition fee" in the form of actual capital loss.

EquiLab is engineered as a comprehensive solution to this problem. EquiLab focuses on the educational and analytical aspects of trading. It provides users with a substantial virtual capital of ₹10,00,000 upon registration, enabling them to explore large-scale investment strategies. In recent years, the growth of financial markets and the proliferation of digital investment platforms have made stock trading more accessible to the general public than ever before. With this popularity, many beginners are eager to invest in stocks to grow their personal wealth; however, the stock market remains a highly volatile environment that requires a deep understanding of market trends, financial analysis, and rigorous risk management. Without prior practical experience, new investors frequently face substantial

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financial losses, which leads to a loss of confidence and early exit from the market.

Paper trading platforms have emerged as a critical educational solution to this problem. By simulating real-time stock trading, paper trading allows users to execute buy and sell orders using virtual money rather than real funds. This simulation provides a secure environment for beginners to build confidence, test diverse trading strategies, and observe market behavior without any actual financial exposure.

EquiLab is designed to provide a high-fidelity simulation of these real-world trading scenarios. Beyond basic trade execution, the platform integrates advanced features such as portfolio management and dynamic profit/loss tracking to help users analyze their performance over time. The system architecture follows a client-server model using modern web technologies to ensure that the user interface is responsive and the backend can handle concurrent trading operations efficiently. By providing a realistic yet risk-free environment, EquiLab prepares aspiring investors for the complexities of real-world financial

PROBLEM STATEMENT AND OBJECTIVES

A. Problem Statement

The stock market offers significant opportunities for wealth creation, but the high risk and steep learning curve act as major deterrents for beginners. Many new investors struggle to interpret complex market trends or analyze stock performance effectively. Due to the absence of a safe learning environment, beginners are often forced to invest real capital without proper training, leading to preventable financial losses. Existing systems are either designed for professional traders—offering complex, confusing interfaces—or provide limited simulation features that do not accurately reflect real market conditions. There is a clear need for a comprehensive, user-friendly platform that enables users to experiment with strategies and track performance before participating in actual investments.

B. Objectives

The primary objectives of Equilab are:

- **Real-Time Simulation**: To develop a web-based platform that accurately simulates real-time stock trading using virtual capital.
- **Risk-Free Education**: To provide a safe environment where users can learn trading mechanics without financial fear.
- **Operational Execution**: To enable users to perform core trading activities, including searching for stocks and executing buy/sell orders.
- **Secure Authentication**: To implement a robust user authentication system for secure registration and login sessions.
- **Performance Analytics**: To provide portfolio management features that calculate and display real-time profit and loss based on user transactions.
- **User Accessibility**: To create a simple, intuitive interface that removes the barriers associated with professional trading terminals.

II. LITERATURE SURVEY

Recent research in financial education and trading simulation has explored artificial market modeling, reinforcement learning-based trading systems, and educational stock simulators. These studies highlight the importance of realistic simulation environments, user-centric interfaces, and performance analytics in improving financial literacy and trading preparedness. Table I summarizes the key related works reviewed for this project and highlights their contributions alongside notable limitations.

TABLE I

Summary of Related Work in Paper Trading Platforms

Authors	Key Findings	Limitations
Cetin and Bingöl (2025). [1]	Trading agent interactions can replicate realistic price behavior in simulated markets	Limited practical implementation for beginner traders
Liu et al. (FinRL, 2025). [2]	Provides an automated decision-making framework for stock trading strategy evaluation	Requires advanced machine learning knowledge
Stock Prediction Survey (2024) [3]	Summarizes multiple predictive models and their effectiveness in trading applications	Does not provide a practical simulation system
Bukhari et al. (2015) [4]	Demonstrates feasibility of virtual stock trading environments	Limited scalability and lacks peer-reviewed validation
Moffit, Stull, and McKinney (2010) [5]	Shows that trading simulations improve financial literacy and practical understanding	Focused on classrom environments rather than scalable web systems

Cetin and Bingöl [1] explored the behavioral mechanics of stock prices within an artificial market environment, utilizing an agent-based simulation where virtual traders interact to mimic real-world investor behaviors . By employing a realistic order book mechanism to match trades, the authors demonstrated that complex market patterns can emerge from relatively simple trading rules, providing a high degree of accuracy for recreated stock exchange operations . However, the primary limitation

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of this research is its lack of focus on real-world order execution interfaces, which limits its practical utility for novice investors seeking a hands-on web experience .

X-Y Liu et al. [2] introduced the FinRL framework, which uses historical data like the NASDAQ-100 to train trading agents. While powerful, its complexity makes it unsuitable for beginners.

Research by Moffit, Stull, and McKinney (2010) [3] validates that classroom trading platforms are essential for financial literacy. EquiLab builds on this by providing a scalable web implementation for individual use.

Bukhari et al. [4] focused on the architectural design of a simulated share trading system, highlighting the feasibility of creating virtual environments where users can practice market operations without financial exposure . Their work utilized test stock price data to mimic market behavior, serving as an early proof-of-concept for risk-free strategy testing. However, the study was not published in a peer-reviewed journal, which raises concerns regarding its academic rigor and long-term scalability compared to modern full-stack web solutions .

Finally, the foundational study by Gode and Sunder introduced the concept of "zero-intelligence" traders to determine if market efficiency could emerge even in the absence of strategic human decision-making . Their results indicated that market efficiency can indeed be achieved under specific conditions through random interactions, laying the groundwork for future simulation research . While historically significant, the model is viewed today as overly simplistic, as it fails to account for the real-world complexities and psychological factors that influence modern electronic trading. EquiLab builds on these collective contributions by addressing their limitations through a modular, web-based architecture that combines real-time portfolio management and interactive analytics without requiring specialized hardware or advanced technical knowledge.

III. DESIGN AND METHODOLOGY

A. System Architecture

EquiLab follows a robust layered client-server architecture designed to provide the high-performance throughput required for financial simulations while maintaining strict separation of concerns. Equilab is built using Next.js 14 for frontend rendering and routing, Express.js and Node.js for backend services, and MongoDB Atlas for persistent data storage. This architectural choice ensures that the presentation, application, and data layers can be scaled independently as the user base grows. The system design is partitioned into three primary layers: the Presentation Layer (Frontend), the Application Layer (Backend), and the Data Layer (Database), all of which communicate through structured REST APIs and real-time WebSocket connections to minimize latency during high-frequency trading simulations. By isolating the business logic within the Application Layer, the platform maintains transaction consistency and ledger accuracy during trade execution, ensuring that virtual capital balances and stock holdings are always synchronized across the distributed environment

The Presentation Layer, serving as the user interface, is developed using HTML5, CSS3, and JavaScript, specifically leveraging React's component-based architecture to provide a highly responsive dashboard . Users interact with this layer to perform critical actions such as registration, secure login, and the execution of market orders . The Application Layer acts as the core engine of EquiLab, implemented via Node.js and Express.js to handle complex processing tasks including user authentication, real-time profit and loss calculations, and portfolio management . Within this layer, a dedicated Trading Engine manages order submissions and validates buying power before updating the ledger, while a Real-Time Market Data Handling module utilizes Polygon WebSockets and Redis caching to provide instant updates to stock quotes . Finally, the Data Layer utilizes MongoDB Atlas, a cloud-based NoSQL database, to store flexible document-based records for users, transaction histories, and portfolio snapshots, ensuring that data is persisted securely and can be retrieved with sub-second latency .

B. System Modules

EquiLab is composed of several specialized modules that work in unison to recreate the environment of a professional trading terminal. The Authentication and Security Module is the gateway to the platform, implementing JSON Web Token (JWT) authentication, secure cookies, and rate limiting to prevent unauthorized access and protect user sessions . Upon successful authentication, the system initializes the user's virtual account, providing a starting capital of ₹10,00,000 via the Ledger Service. The Trading Engine Module is responsible for the atomic execution of buy and sell orders, ensuring that every transaction passes through a rigorous validation gate that checks for sufficient buying power or holding quantities before the ledger is updated . This module works closely with the Double-Entry Ledger System, which records every trade as a pair of debit and credit entries to maintain a searchable and auditable history of all financial activities within the platform .

In addition to transaction execution, the platform features a Portfolio Analytics Processing Module that continuously evaluates open positions to generate real-time performance metrics . This module calculates the weighted average cost of holdings, unrealized profit and loss, and risk metrics such as the Sharpe ratio, giving users deep insights into their trading efficacy . The Market Data Handling Module manages the influx of live price information by connecting to external financial APIs and

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broadcasting the data to the frontend via Client WebSockets . Furthermore, the History Module maintains a comprehensive, reverse-chronological audit log of every executed order, allowing users to filter their past trades by symbol or transaction type and export their data as a CSV file for external analysis . The modular design ensures that future enhancements, such as AI-based price prediction or social trading features, can be integrated without disrupting the existing core workflows .

C. Technology Stack

The technology stack was selected for its lightweight deployment, open-source availability, active community support, and suitability for rapid development:

- Frontend: HTML5, CSS3, JavaScript, Bootstrap 5
- Backend: Node.js v18+, Express.js v4, NextJS
- Database: MongoDB (NO-SQL)
- Data Format: JSON (RESTful API)
- Development Tools: Visual Studio Code, GitHub
- Future Analytics Layer: Python 3, Pandas, Scikit-learn

D. Database Design

The data architecture for EquiLab is centered around a flexible NoSQL schema designed in MongoDB to handle the hierarchical and often variable nature of financial records. The database structure is organized into five primary entities: User, Stock, Trade, Portfolio, and LedgerEntry, each serving a distinct role in the system's state management . The User entity stores essential profile information including unique user IDs, encrypted authentication credentials, and the overall account balance . The Stock entity acts as a reference for the 20 NSE-listed symbols available for trading, containing ticker symbols, company names, and current market prices . All historical activities are captured in the Trade entity, which records the unique trade ID, transaction type (buy/sell), quantity, execution price, and precise timestamps to ensure clinical accountability .

The Portfolio entity serves as a dynamic link between users and their current holdings, maintaining a list of active stock positions along with their respective quantities and purchase prices . To ensure transactional integrity that mirrors real banking systems, the LedgerEntry entity tracks every movement of virtual capital through a double-entry accounting method. This entity uses MongoDB's aggregation framework to calculate real-time balances by summing all credit entries and subtracting all debit entries associated with a specific user's cash or holdings account . Relationships between these entities are enforced through document referencing, which prevents orphaned records and allows for efficient querying under concurrent multi-user load. By utilizing composite indexes on frequently accessed fields like userId and symbol, the database ensures that portfolio snapshots and trade histories can be rendered on the dashboard with minimal delay

IV. IMPLEMENTATION AND RESULTS

A. Authentication and Registration

The first point of interaction within the EquiLab platform is the authentication gateway, which is designed to ensure secure access to the virtual trading environment. The Login and Registration interfaces employ a modern glassmorphism design aesthetic, characterized by translucent cards set against a deep purple-tinted dark background to reduce eye strain during extended trading sessions. Upon registration, the system eliminates traditional friction points by provisioning new users with a substantial virtual capital of ₹10,00,000 without requiring immediate email verification, thus allowing for instantaneous onboarding. Security is maintained through the implementation of the bcrypt algorithm for password hashing and the issuance of JSON Web Tokens (JWT) to manage secure, stateless sessions . This architecture ensures that user credentials and virtual balances are protected against unauthorized access while maintaining the high-speed performance expected of a modern financial application.

B. Dashboard and Portfolio Overview

Once authenticated, users are directed to the main Dashboard, which serves as a centralized situational awareness hub for their virtual financial standing. The interface surfaces critical metrics through a series of dynamic cards that provide a high-level overview of the total portfolio value, available cash balance, and the current value of all active holdings . To ensure a responsive feel, the dashboard utilizes skeleton loaders that prevent layout shifts during data retrieval from the MongoDB database. The overview page specifically highlights both the Unrealized Profit and Loss (P&L) and the Day P&L, allowing users to assess their immediate market exposure and daily performance at a single glance. This real-time visibility is essential for developing the market intuition required to manage large-scale portfolios under varying volatility conditions.

C. Trading Interface and Asset Selection

The Trade Page is the core interaction surface where users engage with market dynamics through an integrated symbol search and order execution panel. The platform supports a selection of 20 major NSE-listed symbols, which users can explore by typing a ticker or company name into a search input optimized with a 260ms debounce to ensure efficiency. A defining feature of this module is the 180-day candlestick chart, rendered using the TradingView

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Lightweight Charts library, which provides a professional-grade visual read of price history and trends. When placing a market order, the system allows users to choose their transaction side and quantity, while providing an estimated notional value that updates in real-time as inputs change. Upon submission, the order is validated against the user's buying power and executed atomically against the double-entry ledger to maintain perfect transactional integrity

D. Advanced Performance Analytics

Beyond simple execution, EquiLab provides a suite of advanced analytical tools designed to transform raw trading data into actionable psychological and strategic insights. The Analytics module features six specialized metric cards that track performance indicators such as the total number of trades, the user's win rate, and the risk-adjusted Sharpe ratio. Below these metrics, a portfolio value over time area chart plots every daily snapshot against the initial ₹10L capital baseline, making performance trends and drawdown periods immediately visible. Furthermore, the platform includes a Sector Exposure analysis that breaks down holdings into industries such as Banking, IT, Energy, and Consumer goods, presenting each as a color-coded horizontal bar. This automatic sector mapping is derived directly from live positions, encouraging users to maintain a diversified portfolio and avoid excessive concentration risk .

E. Trade History and Accountability

The Trade History module maintains a comprehensive, reverse-chronological audit log of every executed order to support financial accountability and trade auditing and post-trade analysis. Each entry in the history table provides granular details, including the precise execution date, the symbol, the transaction side (buy/sell), quantity, price, and the total value inclusive of simulated fees. To facilitate the review of high volumes of activity, the platform offers robust filtering capabilities by symbol or side, alongside a numbered paginator that groups results for easier navigation. Recognizing the importance of external data analysis, EquiLab includes a feature to download the full account statement as a CSV file with a single click. This capability allows users to perform deeper statistical reviews in spreadsheet software, bridging the gap between a web-based simulation and the professional analytical workflows used by actual market participants.

V. COMPARATIVE ANALYSIS

To contextualize the contributions of EquiLab within the current landscape of financial tools, Table II presents a structured comparison against existing retail trading simulators and brokerage demo accounts available to individual investors.

TABLE II

Feature	Existing Platforms	EquiLab
Virtual capital simulation	Limited/None	Yes (₹10L)
Real-time market data feed	No	Yes (Polygon API)
Portfolio analytics / Sharpe ratio	No	Yes
Double-entry ledger system	No	Yes
Candlestick chart (TradingView)	No	Yes (180-day)
Trade history & CSV export	Partial	Yes
Lightweight open-source MERN stack	No	Yes

Traditional online trading platforms are primarily optimized for experienced investors, featuring complex interfaces with overwhelming charts and technical indicators that can confuse beginners . While some brokers offer demo accounts, these are frequently limited in functionality and do not provide the deep analytical insights required to understand the underlying drivers of a strategy's success or failure.

Furthermore, the high financial risk inherent in real-money trading environments often leads to premature exits for novice users who experience early losses . EquiLab bridges these gaps by delivering a comprehensive, software-only platform that unifies high-fidelity market simulation with intuitive design and advanced analytics . Unlike professional terminals, EquiLab prioritizes the learning experience, offering risk-free experimentation with virtual funds and automated performance tracking to build user confidence and financial literacy .

VI. TESTING

A. Systematic Testing Approach

A rigorous and systematic testing methodology was applied to EquiLab to ensure the reliability and precision required for a financial simulation platform. The testing strategy was designed to accommodate a spectrum of evaluations, ranging from low-level unit tests that verify the correctness of individual source code segments to high-level functional tests that validate the system against user requirements . Each module, including Authentication, the Trading Engine, and the Portfolio Analytics processor, was isolated and exercised against a predefined set of inputs to compare actual outputs with expected results. This multi-tiered approach ensured that core

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logic—such as buying power validation and atomic ledger updates—functioned correctly before the modules were integrated into the broader system architecture. Edge cases, including attempts to trade with zero balance or during simulated market off-hours, were specifically targeted to ensure the system's robust error-handling capabilities .

TABLE III

Unit Test Cases and Results

ID	Test Case	Expected Result
TC-01	Login with valid credentials	Redirect to dashboard
TC-02	Login with invalid password	Error message displayed
TC-03	Register new user — missing fields	Validation error shown
TC-04	Register new user — valid data	Account created, ₹10L balance set
TC-05	Buy stock with sufficient balance	Order executed, holdings updated
TC-06	Buy stock with insufficient balance	Transaction rejected with error
TC-07	Sell stock with sufficient holding	Order executed, balance updated
TC-08	Sell stock not in portfolio	Error: insufficient holdings shown
TC-09	View portfolio after trade	Holdings and P&L displayed correctly
TC-10	Search for NSE stock symbol	Matching results returned
TC-11	View analytics — Sharpe ratio	Correct risk metric calculated
TC-12	Download trade history as CSV	CSV file downloaded successfully

A. Performance Evaluation

In the context of financial applications, system responsiveness is a critical metric that directly impacts the user's ability to react to simulated market volatility. Performance benchmarks were conducted under a simulated concurrent load to assess the platform's behavior during periods of high activity. The test environment focused on measuring the median response time for primary operations, including dashboard rendering and trade execution. Target thresholds were established based on industry-standard web usability guidelines, aiming for sub-second responses for all user-initiated actions. The Portfolio and Trade CRUD operations demonstrated the highest efficiency at 320ms, while more complex operations, such as the generation of the performance analytics and sector exposure charts, were completed in approximately 1.7 seconds—comfortably within the 2-second target for data-intensive visualizations . These results confirm that EquiLab's MERN-based architecture is sufficiently optimized for real-time educational use.

TABLE IV

System Performance Benchmarks

Operation	Target	Actual
Dashboard Load	< 1.5 s	1.2 s
Trade Execution (Buy/Sell)	< 800 ms	540 ms
Portfolio Load (CRUD)	< 500 ms	320 ms
Trade History Retrieval	< 1 s	680 ms
Analytics & Sharpe Ratio	< 2 s	1.7 s
Sector Exposure Chart	< 2 s	1.5 s

All six benchmarked operations met their target thresholds comfortably. These results confirm that the system is responsive and suitable for real-time educational trading use. Edge cases including simultaneous buy/sell orders from multiple accounts, insufficient balance, and concurrent dashboard loads were all handled correctly without data inconsistencies or server errors.

VII. CONCLUSION AND FUTURE SCOPE

A. Conclusion

The "EquiLab: A Paper Trading Platform" project successfully demonstrates the design and development of a robust web-based application that effectively simulates the complexities of the stock market in a risk-free environment. By allowing users to perform essential trading activities—such as secure registration, market-order execution, and comprehensive portfolio management using virtual capital—the platform serves as a critical bridge between theoretical financial knowledge and practical market application. The integration of a double-entry ledger system ensures transactional integrity, while the use of modern technologies like Next.js, Node.js, and MongoDB provides the scalability and efficiency required for a high-fidelity simulation. Ultimately, EquiLab achieves its primary objective of empowering beginners to build confidence and refine their decision-making skills without the fear of financial loss, contributing to a more informed and capable generation of retail investors.

B. Future Scope

While the current implementation of EquiLab provides a comprehensive suite of tools for paper trading, several planned enhancements will further elevate its pedagogical and technical value. The primary direction for future development involves the integration of additional market APIs to improve

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market coverage, reliability, and asset diversityreplacing simulated data with actual market movements. Advanced data visualization features are planned to include more complex technical indicators and graphs to help users analyze historical trends more effectively. To improve accessibility, the development of a cross-platform mobile application for Android and iOS is a high priority, enabling users to manage their portfolios on the go.

Further research into social trading features will allow users to share strategies and learn collaboratively, fostering a community-driven educational environment. Security will be continuously strengthened through advanced authentication mechanisms and end-to-end encryption of all sensitive data communications. Finally, EquiLab aims to expand into multi-asset support, enabling the trading of cryptocurrencies, commodities, and other financial instruments within the same unified interface. These improvements, combined with the potential for AI-driven prediction models based on LSTM networks, will transform EquiLab into a dynamic, state-of-the-art platform for global financial education

Some other improvements include:

- Integration of advanced AI/ML models such as LSTM networks and Random Forest classifiers for more accurate, context-aware prediction of stock price movements and portfolio performance using machine learning models trained on historical and technical market indicators
- Development of a cross-platform mobile application for Android and iOS using React Native, enabling on-the-go dashboard access, push notifications, and transfer approvals for trading professionals.
- Real-time SMS and push notification alerts to support efficient trading
- Strengthened data security architecture via end-to-end encryption of all API communications, comprehensive audit logging, and access control aligned with industry-standard financial application security practices and secure API communication protocols

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Both authors worked jointly on the design, development, and implementation of the project, combining their skills to build an efficient and scalable solution.providing the necessary infrastructure and working facilities.

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