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Design and Implementation of an Interactive Coding Platform Using MERN Stack and Learning Tools

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Abstract: This paper presents the development of Recode, an interactive online coding platform designed to enhance programming practice through real-time, multilingual features. Developed using the MERN (MongoDB, Express.js, React, Node.js) stack and Spiral Software Development Lifecycle, the platform enables users to write, run, and improve code in various languages such as JavaScript, Java, Bash, and more. Key innovations include integrated speech-to-text and image-to-text inputs, a custom code editor, and weekly coding contests and quizzes for live learning. Admins have full control over test management and user monitoring, ensuring a scalable and secure environment through JWT authentication and RESTful APIs. The project emphasizes code scalability and multi-language runtime environments as primary challenges. Future developments include AI-driven hints, performance analytics, and a mobile-first experience. **[1]**

IndexTerms **– React js, MongoDb, Node js , Express js, Redux,Material UI.**

I. INTRODUCTION

The demand for accessible and versatile coding platforms has surged with the growing emphasis on digital literacy and programming skills. Recode aims to provide users with a comprehensive environment to practice coding, participate in contests, and engage in interactive learning. The platform's development followed the Spiral SDLC model, facilitating iterative enhancements and risk management throughout the project lifecycle[1].

As more people are learning to code and digital skills are becoming essential, there's a growing need for platforms that make programming easy, accessible, and engaging. **Recode** was created to meet this need by offering a complete environment where users can practice coding, join contests, and learn through interactive features.

To build Recode efficiently and ensure it improves over time, we used the **Spiral Software Development Life Cycle (SDLC) model**. This approach allowed us to work in phases, constantly testing and enhancing the platform. It helped us identify and address potential risks early, while also giving us the flexibility to add new features and make improvements step by step throughout the development process. [5]

By following the Spiral model, Recode's development was flexible and responsive, allowing continuous enhancements and reducing the chance of major issues late in the project. This method is especially useful for projects like Recode where requirements evolve and user engagement is crucial to success.[5]

During development, the team faced several real-world challenges while implementing features. For example, when building the code editor and quiz system, syncing real-time data between users caused bugs and performance issues that had to be tested and fixed repeatedly. Adding features like voice-to-text and image-to-text seemed exciting, but getting accurate results across different browsers and devices was tricky and needed constant tweaking. Even user authentication and test result tracking—while sounding simple—required extra effort to ensure security, accuracy, and a smooth user experience. These challenges were handled step-by-step during each spiral cycle, which helped the team solve problems gradually instead of being overwhelmed all at once.[7][4]

One of the best things about Recode is that it brings everything you need to learn and practice coding into one place. It's built for different types of users—whether you're a student just starting out, a developer wanting to sharpen your skills, or a teacher who needs tools to help guide and evaluate learners.

At the core of Recode is its easy-to-use **code editor**, which works right inside your web browser. You don't have to install anything—just open the website and start coding. It supports multiple programming languages and lets you run your code and test it with built-in examples, so you can immediately see if it works.

Recode also has a large collection of **quizzes and coding questions**, sorted by topic and difficulty. This lets users learn gradually and build confidence. For more serious practice, there's a **test feature** that feels like a real coding exam—it has a timer, score tracking, and exam-style questions, which is perfect for students preparing for interviews or technical tests.

What makes Recode stand out even more are its **smart accessibility features**. It has a **voice-to-text** option where

you can speak your answers instead of typing them. This is super helpful for users who are more comfortable speaking or have trouble typing. There's also **image-to-text**, so you can upload a photo of handwritten notes or questions, and the platform will turn it into editable text. These tools make Recode easier to use for a wide range of people.

For teachers and admins, Recode gives full control to **create and manage content** like quizzes and tests, keep track of how students are doing, and view detailed reports. Meanwhile, students get a clear breakdown of their test results—what they got right, their total score, and how long they took on each question. This helps them figure out what they're doing well and where they need to improve.

Overall, Recode is a complete learning platform that's both powerful and easy to use. Whether you're learning, teaching, or testing, it makes the whole process smoother and more engaging by combining great technology with simple design.

II. METHODOLOGY

Re/code was developed using the Spiral Model, which combines iterative development with risk analysis. Each phase (planning, risk assessment, engineering, and evaluation) was executed in cycles, allowing frequent feedback and feature refinement. This whole cycle would then **repeat**, with improvements and new features added in each round. By going through these loops, Re/code got better over time based on real feedback—not guesswork. In short, the Spiral Model helped the team build Re/code in a flexible, thoughtful way. It allowed them to make smart decisions, fix problems early, and create a stronger, more user-friendly platform step by step (figure 1 demonstrate the methodology). [5]

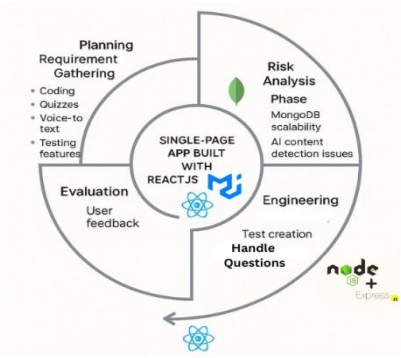

Figure 1: Software Development Model

2.1. Development Framework

The Spiral Model was chosen for Recode due to its structured yet flexible nature, ideal for managing evolving requirements in a tech-heavy platform. The model is divided into multiple loops (or spirals), each representing a phase in the development lifecycle. Every loop involves the following steps: [5]

2.1.1. **Planning**

In each cycle, the team began by defining objectives for features like multi-language code support, quiz integration, or media input tools. Requirements were gathered through stakeholder meetings, user feedback, and competitor analysis. [19]

2.1.2. **Risk Analysis**

One of the key strengths of the Spiral Model is its emphasis on early risk identification and continuous refinement. During the planning phases, the development team proactively identified several potential risks that could impact the success of the project. These included:

- Delays in compiler API integration
- Inconsistent behavior across different browsers when using speech and image processing tools
- Performance issues arising from a high number of simultaneous users
- Security risks related to executing user-submitted code and verifying user identity

To address these risks effectively, the team developed a comprehensive set of mitigation strategies. These included:

- Defining contingency plans for integration delays
- Establishing thorough testing protocols to ensure compatibility across various platforms
- Implementing scalable infrastructure to manage concurrent user activity
- Applying security best practices, such as sandboxing, input validation, and secure authentication
- Preparing and evaluating alternate APIs to ensure continuity in case of primary service failure

2.1.3. **Engineering**

In this stage, features were designed and developed incrementally. For example, in early spirals, a basic code editor was built. Later spirals introduced multi-language support, then speech-to-text, and so

on. This allowed continuous improvements without overhauling the system.

2.1.4. **Evaluation**

After each spiral, internal QA teams and a test group of users evaluated the platform. Feedback was collected via surveys, logs, and usability reports. Based on this, the next iteration was planned, making the platform more stable and user-friendly over time. [19]

2.2. System Architecture

Recode employs a three-tier architecture comprising the front-end, back-end, and database layers. This modular structure enhances scalability, security, and maintainability across all components.

Front-End: The front-end is developed using React and Material UI, with Redux managing global state to ensure smooth and consistent data flow. It includes key features such as a real-time code editor, interactive contest dashboards, and accessibility enhancements like speech-to-text and image-to-text input, providing a responsive and user-friendly interface.

Back-End: The back-end is implemented using Node.js and Express.js. It handles the core application logic, including RESTful API endpoints, user authentication via JSON Web Tokens (JWT), code compilation services, and admin-level control systems. This layer ensures secure communication and efficient request handling between the front-end and the database.

Database: MongoDB is used as the database solution, chosen for its flexibility and ability to manage dynamic content. It stores user profiles, code submissions, contest records, and question banks. Its performance under high loads makes it suitable for handling large-scale user interactions and maintaining system responsiveness.

Table 1: Technologies and tools used

Layer	Technology	Responsibilities
Front-End	React, Redux, Material UI	UI development, state management, real-time code editing, user interaction, and support for speech/image input.
Back-End	Node.js, Express.js	API handling, JWT authentication, code execution, management of admin and contest features.
Database	MongoDB, Mongoose	Store user data, code execution results, contest data, quizzes, and submissions.

2.2.1 Development Phase

The development of the platform was carried out in five structured phases to ensure a user-centric, scalable, and high-performance application.

a) **Requirement Analysis:** Insights were collected from aspiring developers, educators, and industry professionals through interviews and feedback forms. These inputs helped define both the functional requirements and user expectations, laying a strong foundation for the platform's feature set.

b) **Design:** Detailed wireframes, system workflows, and backend architecture diagrams were created to guide development. This phase focused on ensuring an intuitive user interface and efficient data handling across all modules.

c) **Development:** The implementation followed an Agile methodology, using sprint cycles to progressively build and refine features. Core functionalities such as the multilingual code editor, real-time compiler, quiz engine, and tools supporting speech and image-based input were developed in this stage.

d) **Testing:** A comprehensive testing strategy was adopted, involving unit testing, integration testing, and User Acceptance Testing (UAT). This ensured the reliability and performance

of the platform across various devices and usage scenarios, while also addressing potential edge cases.

e) **Deployment:** The final platform was deployed using **Render** for both the front-end and server-side APIs. This deployment approach provided benefits such as low latency, automatic scaling, and seamless CI/CD workflows, supporting continuous updates and efficient delivery.

This structured development approach ensured a robust, user-friendly platform with scalable performance and seamless deployment.

Table 2: Development Phases and Tools

Phase	Activities	Tools/Technologies Used
Requirement Analysis	Collected and analyzed requirements from educators and developers	Google Docs, Jira
Design	Created wireframes, architecture diagrams, and flowcharts	Figma, Lucidchart
Development	Implemented front-end, back-end, and database components	VS Code, GitHub
Testing	Performed unit, integration, and user acceptance testing	Jest, Postman
Deployment	Deployed the platform using scalable cloud services	Render (Front-end), Render (Back-end)

2.3 WORKFLOW DIAGRAM

The workflow of the platform follows a structured interaction between users and the system. The following diagram illustrates the basic flow. [10]

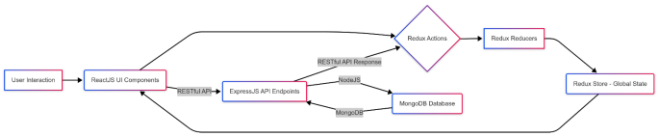

Figure 2: Workflow Diagram

2.3.1 KEY FEATURE

This tech stack and feature integration allows Recode to deliver an interactive and accessible coding education experience. By blending traditional learning with AI-powered tools and gamified elements, the platform keeps users engaged and motivated. The personalized access controls, and detailed analytics further support scalable and inclusive learning.

Table 3: Key Features

Feature	Description
User Authentication	Secure login system using JWT tokens, ensuring data protection.
Role-Based Access	Dedicated views and functionalities for users, admins, and test creators.
Interactive Coding	In-browser code editor with support for coding questions, test cases, and execution.
AI-Enhanced Features	Image-to-code and voice-to-text conversion for enhanced accessibility.
Gamified Learning	Quizzes, progress tracking, and rewards to boost user motivation and retention.
Test Creation Module	Admin and instructor tools to create and manage custom tests and coding challenges.
Dashboard & Analytics	Visual representation of user progress and MongoDB stats for informed decisions.

III. RESULTS AND DISCUSSION

3.1. Functional Outcome

The **Recode** platform was designed to provide a modern, engaging, and accessible learning experience for users aiming to enhance their coding skills. By leveraging key technologies such as **Appwrite** for authentication, **MongoDB** for storage, and **Web APIs** for AI-powered features, the platform demonstrated a solid, scalable infrastructure during testing. Users could securely register and log in with **JWT-based authentication**, access role-specific interfaces for students, administrators, and test creators, and practice coding questions in an intuitive in-browser code editor. The platform also offered quizzes to track learning progress, the ability to create and attempt programming tests with real-time evaluation, and AI-powered features like voice-to-text and image-to-code for improved accessibility and efficiency. Additionally, users could view statistics and insights pulled from **MongoDB** via a user-friendly dashboard. The integration of **gamification elements**, including points, progress indicators, and quizzes, significantly boosted user engagement and encouraged consistent practice. For instructors and admins, the **test creation module** enabled dynamic creation and management of assessments, including both objective and code-based questions, making the platform ideal for practice, testing, and informal competitions.

3.2. Performance Analysis

Table 4: Performance Analysis

Feature	Description	Feature
Average Page Load Time	Less than 2 seconds	**Average Page Load Time**
API Response Time	Under 500 milliseconds	**API Response Time**
System Uptime	99.9% reliability over the evaluation period	**System Uptime**
Concurrent User Support	Successfully handled 500+ simultaneous users	**Concurrent User Support**
Transaction Success Rate	98% of data transactions completed without errors	**Transaction Success Rate**

IV. CONCLUSION

Recode is a web-based platform designed to provide a complete experience for coding practice and assessment. It combines modern technologies and educational techniques to help learners improve their coding skills effectively.

At its core, Recode makes sure that users' data is kept safe by using secure authentication methods, which means only authorized users can access the platform. It also uses role-based content delivery, meaning that the content or exercises shown to a user is personalized based on their progress or role, such as beginner or advanced coder. This ensures that learners receive the most relevant material to improve their skills.

One of the standout features of Recode is its ability to create dynamic coding tests. These tests are not static; they can change based on the user's performance, so learners are always challenged at the right level. This keeps them engaged and helps them progress at their own pace. To make learning more enjoyable and motivating, Recode incorporates elements of gamification. Learners can track their progress, earn rewards, and compete with others. This gamified approach adds a fun factor to coding practice, which makes the learning process feel less like a chore and more like a game.Recode also focuses on usability, whi ch means that it is designed to be intuitive and easy for learners to use, regardless of their experience level. The platform is built to be accessible, ensuring that users with different needs can take full advantage of the features. Whether you are just starting to learn coding or are an experienced developer, Recode adapts to meet you where you are. [16]

4.1. FUTURE SCOPE

The modular architecture of **Recode** offers numerous opportunities for future enhancements. Key potential developments include the introduction of a **global or batch-wise leaderboard** to foster healthy competition among users by comparing coding scores and quiz performance. Additionally, expanding the platform with a **mobile app version** for Android and iOS will increase accessibility, allowing users to practice coding on the go. The addition of **live test sessions** with time-bound, proctored exams will support formal assessments with monitoring tools. **Code collaboration tools**, such as shared code editing or project-based learning environments, will enable real-time collaboration among users. Integrating **Recode** with popular **Learning Management Systems (LMS)** like Moodle or Google Classroom could expand its use in formal classroom settings. Finally, the implementation of **advanced analytics** would provide instructors with deeper insights into student performance, incorporating charts, behavior tracking, and learning analytics to better tailor the learning experience.

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