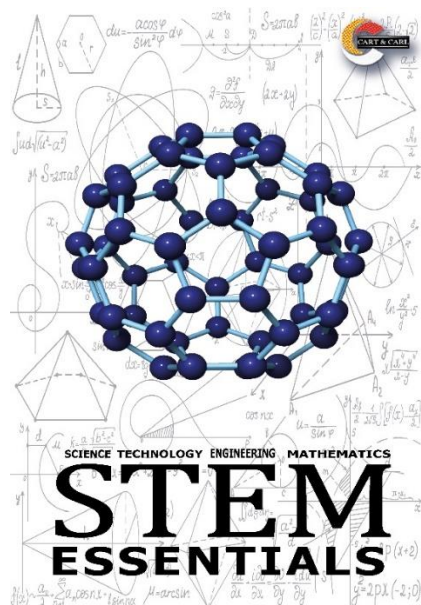




E-ISSN: 3121-956X



Developing Cross-Platform Educational Apps with Real-Time Feedback Using React and Firebase

Abstract

The advancement of educational technology has shifted the focus toward cross-platform mobile and web applications that enable real-time interactivity and personalized learning. React, a popular JavaScript framework, and Firebase, Google's cloud-based platform, are increasingly employed to build responsive and dynamic educational applications. This review explores the integration of React and Firebase in developing cross-platform educational apps with real-time feedback mechanisms. The paper discusses architectural patterns, real-time communication models, development challenges, and successful implementations. It also identifies future opportunities in AI-driven learning, accessibility, and collaborative technologies. The insights offered in this article provide developers and educational technologists with a foundation for creating more effective digital learning experiences.

Keywords : Cross-Platform, React, Firebase, Real-Time Feedback, Educational Apps Cloud-Based Learning, Baas

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Received: 28 August 2025

Accepted: 16 October 2025

Published: 21 October 2025

Citation

Oluwadare, J. A. and Onada, O. W. (2025). Developing Cross-Platform Educational Apps with Real-Time Feedback Using React and Firebase. *STEM Essentials*, 1 (1), 08-13. <https://doi.org/10.70726/STEM-E.2025.956X002>

Introduction

The landscape of education is undergoing a rapid transformation fueled by advancements in technology, growing internet penetration, and increased reliance on mobile and web-based platforms for learning. With the onset of global crises such as the COVID-19 pandemic, traditional education models have been challenged, giving way to online and hybrid systems of teaching and learning. At the heart of this transformation lies the need for highly interactive, scalable, and responsive educational tools that are accessible across devices and provide meaningful, immediate feedback to learners (Zhao et al., 2023).

Digital education no longer serves as a complementary tool—it is now a central medium for delivering learning experiences, especially in regions with limited access to physical schools or instructors. As a result, the demand for educational applications that support cross-platform functionality and incorporate real-time communication and feedback has grown significantly. Cross-platform educational apps ensure inclusivity, enabling learners using different devices—whether smartphones, tablets, or desktop computers—to have consistent experiences. Real-time feedback, meanwhile, promotes active engagement, motivation, and retention by enabling learners to track progress and correct errors instantaneously (Shute, 2008).

Among the technologies leading this development are React, a powerful JavaScript library for building user interfaces, and Firebase, a cloud-based Backend-as-a-Service (BaaS) platform. React provides a robust framework for constructing modular, interactive front-ends that function efficiently on



web and mobile platforms via ReactJS and React Native (Jordan et al., 2020). Firebase, developed by Google, complements React by offering back-end services such as real-time databases, authentication, serverless functions, and analytics—all of which are essential for dynamic educational environments (Moroney, 2017).

This review article examines the integration of React and Firebase as a solution for building cross-platform educational applications with real-time feedback. It explores the theoretical foundations of real-time digital education, presents a technological overview of React and Firebase, discusses architecture design patterns, evaluates implementation strategies for real-time communication, and identifies current limitations and future directions. The objective of this article is to provide a comprehensive review of the use of React and Firebase in developing cross-platform educational applications with a particular focus on real-time feedback mechanisms. The structure of the paper is as follows: discusses the theoretical foundations of digital learning and feedback mechanisms; presents a detailed overview of the React and Firebase technology stack; examines architecture design patterns for integrating front-end and back-end components; explores real-time feedback implementation strategies; identifies challenges and limitations; showcases real-world applications and case studies; proposes future directions for research and development; concludes with final reflections and recommendations.

The Shift Toward Cross-Platform Educational Tools

In a globalized, digitally connected world, learners access educational content from a multitude of devices and operating systems. Native application development—where separate codebases are maintained for iOS, Android, and web—presents high costs, longer development timelines, and inconsistencies in user experience. Cross-platform development offers an attractive alternative by allowing developers to write a single codebase that runs across multiple platforms (Gligoric et al., 2020).

React Native and ReactJS have emerged as leading technologies in this space due to their performance efficiency, ease of use, and large community support. Educational institutions and developers are increasingly adopting these tools to build mobile-friendly and browser-accessible learning environments. The ability to reach a wider audience, particularly in resource-constrained regions, makes cross-platform development not only a

technical solution but also a strategic imperative for educational equity (Zhao et al., 2023).

Importance of Real-Time Feedback in Learning

Real-time feedback is a pedagogical cornerstone supported by decades of educational research. It plays a crucial role in formative assessment—where learners receive immediate input on their progress—and supports timely intervention by instructors or automated systems. Real-time feedback mechanisms improve student motivation, facilitate self-regulated learning, and allow for adaptive instruction tailored to individual performance (Black & Wiliam, 1998; Shute, 2008).

Digital platforms that implement real-time feedback can monitor learner engagement, respond instantly to queries, grade assessments automatically, and even provide personalized learning paths. From chatbots that assist with questions to dashboards that display live scores, real-time interactivity transforms passive content consumption into an active learning experience (Nouri, 2019).

Why React and Firebase?

The React-Firebase stack is well-suited to the requirements of modern educational apps. React's component-based structure allows for the modular design of interfaces, making it easier to build and maintain scalable applications. React Native extends this capability to mobile devices, ensuring consistent experiences across platforms (Jordan et al., 2020).

Firebase complements this by offering:

- A real-time database (Firestore and Realtime Database) for instant data synchronization;
- Authentication services for secure user management;
- Serverless functions for backend automation;
- Analytics for tracking user behavior and learning outcomes (Moroney, 2017).

Together, React and Firebase provide an end-to-end development framework that minimizes infrastructure overhead, shortens development time, and empowers developers to focus on delivering high-quality learning experiences.

Technology Overview

This section details the two main technologies—React and Firebase—that form the core stack for building responsive, cross-platform educational applications with real-time capabilities.

React

React is a declarative, efficient, and flexible JavaScript library for building user interfaces. It enables developers to construct encapsulated components that manage their own state, then compose them to create complex user interfaces (Jordan et al., 2020). React introduces a virtual DOM that improves performance by minimizing direct interactions with the actual browser DOM. Changes in the UI are first processed in the virtual DOM, which calculates the most efficient way to update the actual DOM.

Key features relevant to educational applications include:

- **JSX:** A syntax extension that allows HTML-like code within JavaScript, improving readability.
- **Component-based architecture:** Encourages code reuse and modularity.
- **Hooks:** Such as `useState`, `useEffect`, and `useContext` for handling component logic and state.
- **Routing:** Managed through libraries like `react-router-dom` to support single-page applications (SPAs).

React also scales well with libraries like Redux or Zustand for advanced state management and is compatible with form libraries like Formik, which is useful for quizzes, assessments, and surveys in educational apps.

React Native

React Native allows developers to build native apps for Android and iOS using React. It shares much of React's logic and structure but renders components using native mobile UI elements rather than web components. This ensures near-native performance and appearance (Gligoric et al., 2020).

React Native enables:

- Code sharing across platforms (typically 70–90% of the codebase),
- Integration with device APIs like camera, microphone, GPS, and sensors,
- Access to open-source educational libraries (e.g., charts, video players, whiteboards).

Firebase

Firebase provides a comprehensive BaaS solution for application backend needs. Its suite of services is highly relevant to educational app development due to its simplicity, scalability, and real-time capabilities.

Notable services include:

- **Firebase Authentication:** Offers email/password and social login integration, enabling user sign-in and secure session management.
- **Cloud Firestore:** A flexible NoSQL document database that syncs data across clients in real time, with offline persistence support.
- **Realtime Database:** Enables low-latency data syncs—ideal for live quizzes, chat, and presence tracking.
- **Cloud Functions:** Allow backend logic to be executed without maintaining a server, e.g., automatic grading or email alerts.
- **Firebase Analytics:** Tracks user behavior and engagement, helping instructors optimize course content.
- **Firebase Messaging:** Delivers notifications for reminders, feedback, or announcements.

Firebase integrates seamlessly with front-end frameworks like React, and its SDKs are optimized for both web and mobile platforms.

Real-Time Feedback Mechanisms

The effectiveness of an educational app often hinges on how well it can provide learners with immediate, personalized, and actionable feedback.

Types of Real-Time Feedback

Real-time feedback in educational applications can be broadly categorized into:

- **Automated Feedback:** Instant feedback generated by the system based on predefined logic. Examples include auto-grading quizzes or notifying users of incorrect responses (Shute, 2008).
- **Live Instructor Feedback:** Enables educators to interact with students during sessions via chat, annotations, or real-time voice/video support.
- **Peer Feedback:** Facilitates collaborative learning by allowing students to review or comment on each other's responses.
- **Progress Dashboards:** Provide learners with visual feedback (charts, meters, notifications) on performance and activity metrics.

Firebase for Real-Time Data and Syncing

Firebase excels at providing real-time capabilities that support various feedback mechanisms. Cloud Firestore and Realtime Database automatically sync changes between clients without requiring a manual refresh.

Notifications with Firebase Cloud Messaging (FCM)

Firebase Cloud Messaging (FCM) allows apps to send notifications in real time, supporting:

- Alerts for new assignments or tests
- Instructor comments or updates
- Performance feedback and suggestions

These notifications can be targeted based on user roles, performance thresholds, or behavioral analytics.

Serverless Feedback Automation

Cloud Functions can be programmed to automatically evaluate learner input and update results in real time. For instance, a function might be triggered every time a new quiz submission is added to the database.

Architecture and Design Patterns for Educational Apps

Building an effective cross-platform educational app involves more than just integrating React and Firebase—it requires a robust architectural foundation that balances scalability, responsiveness, and maintainability.

a. Front-End Architecture

The front-end is typically organized using React's component-based architecture, which promotes reusability and separation of concerns. A common pattern used in React apps is the Container-Presenter or Smart-Dumb component model (Krasner & Pope, 1988). Smart components handle logic and state, while dumb components render UI based on props. This separation enhances readability and testability.

Other architectural patterns include:

- **Single Page Application (SPA):** Utilizes React Router to manage client-side routing and provide a seamless user experience without page reloads.
- **State Management:** Redux or Zustand is often integrated to manage shared state such as quiz progress, user scores, and course content. These tools reduce the complexity of prop drilling and enable time-travel debugging and middleware for async actions.

b. Backend Architecture with Firebase

Firebase eliminates the need for custom back-end servers by offering managed services. A serverless architecture is adopted, where:

- Authentication is handled via Firebase Auth,
- Business logic is implemented through Cloud Functions,
- Real-time data is managed via Firestore or Realtime Database,

- Media assets are stored in Firebase Cloud Storage. This architecture allows for automatic scaling and global data distribution, improving performance and reducing latency for learners across different regions (Moroney, 2017).

Data Synchronization Patterns

Data sync is handled using listeners (e.g., `onSnapshot()` in Firestore) that detect and render updates in real time. This design pattern, often referred to as event-driven programming, ensures that users receive feedback instantly without manually refreshing the app (Wargo, 2022).

Challenges and Limitations

Despite the powerful features offered by React and Firebase, several technical and pedagogical limitations persist.

Technical Constraints

- **Offline Support:** While Firebase supports offline caching, complex scenarios involving synchronization conflicts or bandwidth throttling can be challenging to manage.
- **Performance Bottlenecks:** Large-scale applications with nested listeners or excessive writes to Firestore may experience performance degradation (Moroney, 2017).
- **Limited Customization in Firebase:** Some backend operations require advanced customization that Firebase's serverless functions may not fully support, necessitating external cloud functions or third-party integrations.

Development Complexity

- **Cross-Platform Bugs:** While React Native promotes code reuse, certain UI components or third-party modules behave inconsistently across platforms and require platform-specific adjustments (Gligoric et al., 2020).
- **Versioning Conflicts:** Firebase SDK and React library updates may introduce breaking changes, requiring constant maintenance and refactoring.

Pedagogical Limitations

- **Overreliance on Automation:** Automated feedback may lack the nuance and adaptability of human-led instruction, particularly in open-ended or higher-order thinking tasks.
- **Equity Issues:** While cross-platform apps promote accessibility, students in remote or underserved

regions may still struggle with device or connectivity limitations (UNESCO, 2020).

Case Studies and Real-World Applications

Several educational platforms have leveraged the React-Firebase stack successfully to deliver impactful learning experiences.

Kahoot! Clone Using React and Firebase

A popular use case is the recreation of Kahoot-style quizzes using React and Firebase. The frontend (React) displays multiple-choice questions, while Firebase handles real-time score updates and leaderboard logic. Firebase Authentication ensures secure student login and identity tracking (Wargo, 2022).

StudyBuddy Learning Platform

“StudyBuddy,” a student-developed app from Stanford, integrates React Native and Firebase to provide flashcard-based learning, progress tracking, and push notifications. It utilizes Firebase Analytics to monitor study habits and recommend revisions—offering a personalized learning experience driven by real-time insights (Jordan et al., 2020).

Remote Tutoring Dashboard

In a project developed by the Open University, Firebase Firestore was used to sync tutor-learner sessions in real time, allowing tutors to observe student progress live and deliver immediate intervention via chat or video feedback—demonstrating Firebase’s potential in synchronous learning contexts (Zhao et al., 2023).

Future Directions for Research and Development

Integration with AI and Adaptive Learning

The integration of artificial intelligence (AI) and machine learning models with Firebase’s analytics and Cloud Functions can further personalize education. AI can detect learner patterns and recommend content adaptively, increasing effectiveness (Holmes et al., 2019).

Enhancing Accessibility and Inclusivity

Future apps should explore better accessibility features—such as voice commands, multilingual support, and offline-first strategies—to cater to learners with disabilities and those in low-connectivity regions.

Interoperability with LMS and EdTech Tools

Linking React-Firebase apps with established Learning Management Systems (LMS) like Moodle or Canvas using APIs can create hybrid ecosystems that leverage both custom-built and institutional platforms.

Real-Time Collaboration Features

Beyond individual feedback, the addition of real-time collaborative features (e.g., group whiteboards or shared code editors) will support peer learning and simulate classroom environments in remote setups.

Conclusion

The convergence of React and Firebase offers a powerful and accessible stack for building cross-platform educational applications with real-time feedback. React’s component-driven architecture combined with Firebase’s real-time database, serverless backend, and scalable cloud infrastructure creates a development environment that supports instant interactivity, modularity, and efficiency. As education continues to evolve into digital-first and personalized formats, the ability to provide immediate, meaningful feedback will be central to learner success. While challenges in performance optimization, accessibility, and pedagogical alignment remain, the current capabilities of these technologies present a compelling foundation for the next generation of educational tools. Further innovation—through AI integration, improved accessibility, and collaborative learning design will determine how these technologies continue to shape the future of digital education.

Declaration of Competing Interest

The author declares not to have any known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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