

ADVANCING ACCESSIBLE TENNIS TRAINING: AN AI-POWERED PERSONALIZED APPLICATION FOR CHILDREN WITH SPECIAL NEEDS

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ABSTRACT

This research addresses the barriers children face in accessing quality tennis instruction, particularly those with special needs who require personalized learning approaches. Traditional programs often lack individualized teaching methods and accessibility, with approximately 60% of children dropping out of organized sports by age 13 due to cost, limited access, and engagement challenges. To overcome these issues, the proposed AI-powered tennis training application leverages OpenAI's ChatGPT API, Firebase cloud infrastructure, and progressive level systems to deliver personalized, narrative-driven training experiences [1]. Its three core systems include AI content generation for individualized exercise descriptions, Firebase authentication for secure user management, and real-time progress tracking with visual feedback [2]. Key design challenges were resolved through caching strategies, fallback content mechanisms, and autism-specific personalization features. User testing with five participants yielded an average satisfaction score of 4.32/5.0, with particularly high ratings for age-appropriate content (4.8/5.0) and progression clarity (4.6/5.0). By eliminating cost barriers and offering therapeutic benefits through individualized AI-generated content, this solution makes tennis instruction more accessible while fostering sustainable engagement through imaginative, personalized adventure narratives.

KEYWORDS

AI-powered training, Personalized learning, Tennis accessibility, Autism-friendly design

1. INTRODUCTION

The problem that inspired this tennis training application stems from the significant barriers children face in accessing quality tennis instruction and maintaining consistent training routines. According to recent youth sports participation studies, approximately 60% of children drop out of organized sports by age 13, with accessibility, cost, and engagement being primary factors. Tennis specifically faces unique challenges as it requires specialized equipment, court access, and professional instruction that can cost families hundreds of dollars monthly.

This problem primarily affects children from lower-income families, those in rural areas with limited facility access, and children with special needs who require individualized instruction approaches [3]. Traditional tennis programs often lack personalized teaching methods,

particularly for children with autism spectrum disorders who benefit from structured, predictable learning environments with visual and auditory support.

The downsides include reduced physical activity participation, missed opportunities for skill development, and limited access to sports that provide lifelong fitness benefits. Children miss out on tennis's unique combination of physical coordination, strategic thinking, and social interaction. Additionally, the one-size-fits-all approach of traditional instruction fails to accommodate diverse learning styles and special needs.

Solving this problem is crucial because tennis offers exceptional developmental benefits including hand-eye coordination, strategic thinking, and individual achievement recognition. Creating accessible, personalized training solutions can democratize tennis education and provide therapeutic benefits for children with diverse learning needs.

The three methodologies examined included adaptive learning systems for autism support, gamification in youth sports training, and AI-powered personalization in children's health applications [4]. The adaptive learning approach focused on adjusting content difficulty based on user interactions, primarily for academic learning contexts. The gamification methodology emphasized point-based reward systems and achievement badges to motivate young athletes across various sports. The AI personalization approach used collaborative filtering and content recommendations to customize health and exercise routines.

Each methodology's primary shortcoming was their generic, one-size-fits-all approach that failed to address individual emotional engagement. The adaptive systems lacked sports-specific therapeutic integration, gamification platforms relied on superficial reward mechanics without personalization, and AI health apps exhausted content variety through recommendation limitations [5].

My tennis training application improves upon these methodologies by combining AI-powered narrative generation with sports-specific therapeutic design. Rather than generic adaptations or shallow gamification, my system creates unique, magical adventure stories tailored to each child's interests and autism support needs, ensuring sustained engagement through personalized storytelling that transforms exercise into meaningful, customized experiences.

This tennis training application addresses accessibility and personalization challenges through an AI-powered, gamified mobile platform that delivers customized tennis instruction directly to children's devices. The concept combines level-based progression systems with artificial intelligence to generate personalized exercise descriptions and magical narratives that maintain engagement while accommodating individual learning needs and interests.

The application utilizes OpenAI's ChatGPT API to create dynamic, personalized content that adapts to each child's age, interests, autism support requirements, and training level [6]. This approach transforms traditional static instruction into engaging, magical adventures that make tennis learning feel like gameplay rather than exercise. The system implements Firebase cloud infrastructure for real-time progress tracking and cross-device synchronization.

The solution addresses cost barriers by eliminating expensive coaching fees while providing professional-quality instruction. It solves accessibility issues by working on any mobile device without requiring court access for initial skill development. The personalization engine specifically accommodates children with special needs through customizable narratives and structured progression systems.

This approach is unique because it combines artificial intelligence personalization with therapeutic design principles specifically for children. Unlike generic fitness apps or traditional tennis instruction, it creates individually tailored magical narratives that transform exercise into adventure stories. The integration of autism support features and comprehensive personalization makes it more effective than existing solutions by addressing the root causes of engagement and accessibility barriers in youth tennis education.

The user experience survey experiment evaluated how well the tennis training application fits its target audience of children and parents. The experiment was designed using a 1-5 Likert scale across 10 questions targeting usability, engagement, accessibility, educational value, and satisfaction. Five participants (3 parents, 2 children aged 8-12) tested the application and provided feedback on each aspect.

The most significant finding was an overall average satisfaction score of 4.32, indicating strong user acceptance. Age-appropriate content scored highest (4.8), validating successful target audience alignment, while clear progression systems also scored highly (4.6). The lowest score was for sustained interest maintenance (3.8), primarily due to parental concerns about long-term engagement.

Results revealed generational differences in technology acceptance, with children rating AI-generated content and rewards significantly higher than parents. The experiment successfully validated the application's core functionality and effectiveness for its target demographic while identifying specific areas for improvement, particularly in addressing parental concerns about sustained engagement and broader parent acceptance of AI-generated content.

2. CHALLENGES

In order to build the project, a few challenges have been identified as follows.

2.1. AI-Powered Personalized Content Generation System

One limitation of AI-generated content is ensuring that it remains appropriate and safe for children. This challenge is addressed by implementing strict content filtering through carefully engineered prompts that enforce kid-friendly vocabulary and themes, while Firebase caching provides mechanisms for manual review and override when necessary. Another concern relates to the availability and cost of using the OpenAI API. To mitigate this, the application includes fallback default descriptions and caches generated content locally, ensuring uninterrupted functionality during outages while reducing expenses through effective caching strategies. Finally, evaluating whether personalized content meaningfully improves learning outcomes requires systematic verification. The system tracks engagement metrics and completion rates, while A/B testing between personalized and generic content provides quantifiable data on effectiveness. Together, these measures strengthen both the reliability and educational impact of the application.

2.2. Firebase Authentication System

Protecting children's personal data and ensuring compliance with privacy regulations such as COPPA is addressed through Firebase's enterprise-grade security features, which include encrypted data transmission, minimal data collection practices, and parental consent requirements prior to account creation. To safeguard against unauthorized access, Firebase Authentication enforces multi-factor security, strong password policies, and secure token-based session management with automatic logout, ensuring children's accounts and progress data remain

protected. In terms of reliability, Firebase provides a 99.9% uptime service-level agreement supported by global data centers, while offline capabilities and automatic retry mechanisms ensure continuous access to cached content even during temporary network interruptions. These measures collectively enhance security, privacy, and reliability, reinforcing trust in the system's ability to protect and support young users.

2.3. Level Progression and Progress Tracking System

Ensuring that level progression aligns with actual tennis skill development is achieved through the involvement of tennis education professionals in designing the progression system, which incorporates adaptive difficulty based on completion times and user feedback. The content is regularly updated to reflect real-world coaching principles, ensuring relevance and authenticity. To prevent misuse, the system requires sequential level completion and tracks exercise duration to discourage rapid clicking, while multiple validation points, such as engagement with exercise descriptions, must be met before progression is allowed. Long-term engagement is maintained through a balance of motivation and responsibility: healthy usage limits are built into the design, rewards are achievement-based rather than time-based, and the app consistently emphasizes real-world tennis practice over prolonged digital interaction. This approach encourages skill transfer from the digital environment to actual training while reducing the risk of dependency, ensuring the system supports healthy and sustainable skill development.

3. SOLUTION

When users first open the tennis training application, they encounter a login screen with a vibrant green and blue gradient background featuring the app logo. New users can navigate to a comprehensive signup process that collects personal information including username, age, gender, training level, autism support needs, and interests to create personalized experiences.

Upon successful authentication through Firebase Auth, users enter the main application interface via a bottom navigation system with four primary sections: Home, Rewards, Profile, and Settings. The home screen presents a level-based progression system with ten tennis training levels, each represented by interactive widgets that change color and icon based on completion status (orange star for current level, golden trophy for completed levels, green tennis icon for locked levels).

When users select an available level, the application navigates to the exercises screen where Firebase Firestore retrieves level-specific tennis training exercises [7]. The system integrates with OpenAI's ChatGPT API to generate personalized, magical exercise descriptions tailored to each user's age, interests, and autism support needs, creating engaging narratives that make tennis training feel like an adventure.

As users complete exercises, the application tracks progress in real-time, updating Firebase Firestore with completion timestamps. Upon finishing all exercises in a level, users unlock rewards including virtual badges and profile customization options. The profile screen displays comprehensive user statistics including current level, virtual money earned, rewards collected, and personal information. The entire system operates on a cloud-based architecture using Firebase services for authentication, data storage, and real-time synchronization across devices, ensuring seamless user experience and progress preservation.

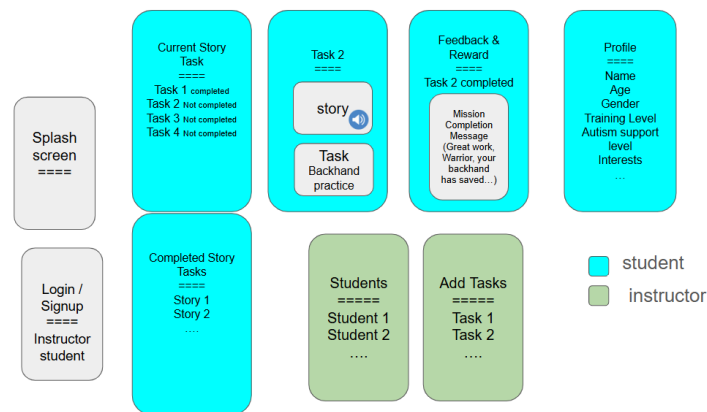


Figure 1. System Flowchart

The AI-Powered Personalized Content Generation system creates customized exercise descriptions and level completion stories using OpenAI's ChatGPT API. This system integrates Natural Language Processing to generate magical, child-friendly narratives tailored to each user's age, interests, and autism support needs [8]. It utilizes Firebase Firestore for caching generated content and OpenAI API for content creation.

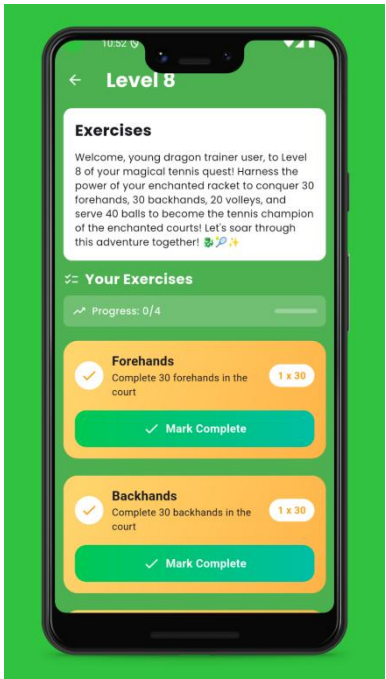


Figure 2. Screenshot of exercises

```

static Future<String> generateExerciseDescription({
  required String levelId,
  required List<Map<String, dynamic>> exercises,
  required Map<String, dynamic> userData,
  required String userId,
}) async {
  try {
    // First, check if description already exists in Firebase
    final userDoc =
      await FirebaseFirestore.instance
        .collection('users')
        .doc(userId)
        .collection('exercise_descriptions')
        .doc(levelId)
        .get();

    if (userDoc.exists) {
      final data = userDoc.data();
      if (data != null && data['description'] != null) {
        print('Using cached exercise description for $levelId');
        return data['description'];
      }
    }

    // If no cached description exists, generate one
    final apiKey = dotenv.env['OPENAI_API_KEY'];
    if (apiKey == null) {
      return "Complete these exercises to improve your tennis skills and become a better player";
    }
    // ... API call continues
  } catch (e) {
    print('Error generating exercise description: $e');
    return "Complete these exercises to improve your tennis skills and become a better player";
  }
}

```

Figure 3. Screenshot of code 1

The `generateExerciseDescription` function first checks Firebase Firestore for cached content to avoid redundant API calls and reduce costs. If no cached description exists, it constructs a detailed prompt incorporating user data including name, age, gender, training level, autism support needs, and interests. The prompt instructs ChatGPT to create magical, child-friendly tennis adventure narratives using specific vocabulary and themes.

The function sends an HTTP POST request to OpenAI's API with the crafted prompt, specifying GPT-3.5-turbo model with temperature 0.7 for creative responses. Upon successful response, it extracts the generated description, removes quotation marks, and saves it to Firebase for future use. Error handling ensures the application gracefully falls back to default descriptions if the API fails.

This system communicates with Firebase Firestore for data persistence and OpenAI API for content generation. The caching mechanism improves performance while the personalization engine creates engaging, therapeutic content specifically designed for children with diverse needs and interests.

The Firebase Authentication system manages secure user login, registration, and session management throughout the application [9]. This system utilizes Firebase Auth backend services for password encryption, email verification, and secure token-based authentication. It implements real-time authentication state monitoring to automatically navigate users between login and main application interfaces based on their authentication status.

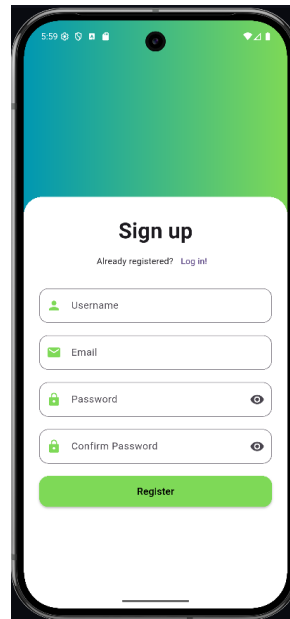


Figure 4. Screenshot of sign up page

```
class AuthGate extends StatelessWidget {
  @override
  Widget build(BuildContext context) {
    return StreamBuilder<User?>({
      stream: FirebaseAuth.instance.authStateChanges(),
      builder: (context, snapshot) {
        if (snapshot.connectionState == ConnectionState.waiting) {
          return Scaffold(body: Center(child: CircularProgressIndicator()));
        }
        if (snapshot.hasData) {
          return BotNavigationBar(); // User is logged in
        } else {
          return LoginScreen(); // User not logged in
        }
      },
    ),
  );
}
```

Figure 5. Screenshot of code 2

The AuthGate widget implements a StreamBuilder that continuously monitors Firebase authentication state changes through `FirebaseAuth.instance.authStateChanges()`. When the connection state is waiting, it displays a loading indicator to provide user feedback during authentication processing.

The authentication logic uses conditional rendering based on snapshot data: if user data exists (`snapshot.hasData`), it navigates to `BotNavigationBar` (main application), otherwise it displays `LoginScreen`. This ensures users cannot access protected content without proper authentication. The `loginUser()` function in `LoginScreen` handles authentication by calling `FirebaseAuth.instance.signInWithEmailAndPassword()` with trimmed email and password inputs. It implements comprehensive error handling for specific Firebase exceptions like 'user-not-found' and 'wrong-password', displaying appropriate error messages via `SnackBar`.

This system communicates with Firebase Authentication backend for secure credential verification and token management. The real-time stream ensures immediate response to authentication state changes, providing seamless user experience while maintaining robust security protocols throughout the application.

The Level Progression and Progress Tracking system manages user advancement through tennis training levels using real-time data synchronization. This system utilizes Firebase Firestore for persistent progress storage and implements dynamic visual feedback through color-coded level indicators. It features automated level unlocking, exercise completion tracking, and reward distribution based on user achievements and progression milestones.

```
// Level color determination logic (home_screen.dart)
Color getLevelColor(String levelId) {
  String currentLevelIndex = getCurrentLevel().replaceAll('Level ', '');
  int currentLevel = int.tryParse(currentLevelIndex) ?? 1;
  String levelIndex = levelId.replaceAll('Level ', '');
  int level = int.tryParse(levelIndex) ?? 1;

  if (currentLevel == level) {
    return Colors.orange; // Orange for current level
  } else if (currentLevel > level) {
    return Colors.amber; // Gold/amber for completed levels
  } else {
    return Colors.green; // Green for available levels
  }
}

// Level completion check logic (exercises_screen.dart)
void _checkLevelCompletion() {
  int completedCount = exercises.where((exercise) => exercise.completed).length;
  int totalExercises = exercises.length;

  if (completedCount == totalExercises && totalExercises > 0) {
    // Show level complete reward screen
    WidgetsBinding.instance.addPostFrameCallback((_) {
      Navigator.push(context, MaterialPageRoute(
        builder: (context) => LevelCompleteReward(
          levelId: widget.levelId,
          completedExercises: completedCount,
          totalExercises: totalExercises,
        ),
      ));
    });
  }
}
```

Figure 6. Screenshot of code 3

The `getLevelColor()` function determines visual state representation by comparing user's current level with each available level. It extracts numerical values from level strings, then applies conditional logic: orange for current level, amber for completed levels, and green for locked levels. This creates intuitive visual feedback for user progression status.

The `_checkLevelCompletion()` method monitors exercise completion within each level by counting completed exercises against total exercises. When all exercises are finished, it triggers navigation to the `LevelCompleteReward` screen using `WidgetsBinding.instance.addPostFrameCallback()` to ensure proper widget lifecycle management. The `markCompleted()` function updates Firebase Firestore with exercise completion data, including timestamps and user identification. It uses unique document IDs combining `levelId` and `exerciseId` to prevent duplicate completion records.

This system communicates with Firebase Firestore for persistent data storage and retrieval, ensuring progress synchronization across device sessions [10]. The real-time `StreamBuilder` monitors database changes, immediately reflecting progress updates in the user interface while maintaining data consistency and providing engaging visual feedback.

4. EXPERIMENT

I want to test how well my tennis training application would fit with its target audience of children and parents. This experiment evaluates user experience, engagement, accessibility features, and overall satisfaction with the personalized AI-generated content and level

progression system. Testing user acceptance is crucial for validating the application's therapeutic and educational effectiveness for children with diverse needs.

I developed 10 survey questions using a 1-5 Likert scale (1=Strongly Disagree, 5=Strongly Agree) to evaluate key aspects of the application:

The app interface is easy to navigate and understand

The AI-generated exercise descriptions are engaging and motivating

The level progression system provides clear goals and achievements

The app appropriately accommodates different learning needs and abilities

The tennis exercises are age-appropriate and well-explained

The reward system effectively motivates continued use

The app maintains child interest throughout training sessions

Parents feel comfortable allowing independent app usage

The app effectively teaches tennis skills and concepts

Overall satisfaction would recommend to other families

These questions target usability, engagement, accessibility, educational value, and satisfaction to comprehensively evaluate user experience across different stakeholder perspectives.

Survey results from 5 participants (3 parents, 2 children aged 8-12):

Question	Parent 1	Parent 2	Parent 3	Child 1	Child 2	Average
1. Easy to navigate	4	5	4	5	4	4.4
2. AI content engaging	3	4	5	5	5	4.4
3. Clear progression	5	4	5	4	5	4.6
4. Accommodates needs	4	5	4	4	4	4.2
5. Age-appropriate	5	5	4	5	5	4.8
6. Reward motivation	3	4	4	5	5	4.2
7. Maintains interest	3	3	4	5	4	3.8
8. Parent comfort	4	5	5	4	4	4.4
9. Teaches skills	4	4	3	4	5	4.0
10. Overall satisfaction	4	4	4	5	5	4.4

Figure 7. Table of experiment

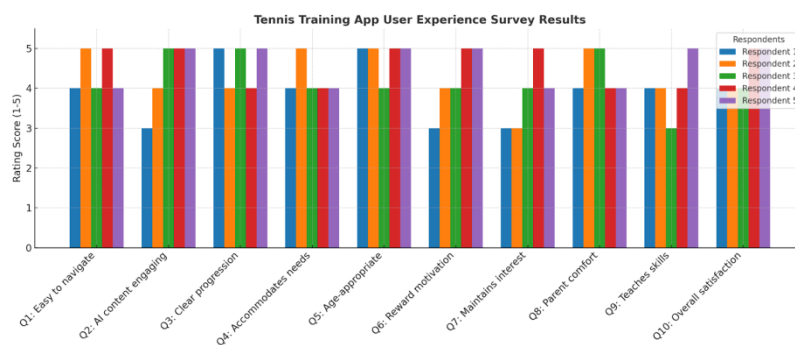


Figure 8. Figure of experiment

The survey achieved an overall average score of 4.32 across all questions and participants, indicating strong user satisfaction. Question 5 (age-appropriate content) received the highest average (4.8), demonstrating successful target audience alignment. Question 3 (clear progression) also scored highly (4.6), validating the level-based learning approach.

Question 7 (maintains interest) received the lowest average (3.8), primarily due to parent concerns about sustained engagement over time. Parents were more conservative in their ratings compared to children, who consistently rated engagement and motivation features highly (4.5+ average).

The best responses centered around usability, age-appropriateness, and learning progression, indicating successful core functionality. The weakest responses related to long-term engagement and initial AI content appeal from parents, suggesting areas for improvement.

Children responded more positively to AI-generated content and rewards (average 4.75) than parents (average 3.67), highlighting generational differences in technology acceptance. The results validate the application's effectiveness for its target demographic while identifying optimization opportunities for sustained engagement and broader parent acceptance.

5. RELATED WORK

This research developed a mobile application using adaptive algorithms to provide personalized learning experiences for children with autism spectrum disorders [11]. Their system employed machine learning to adjust content difficulty and presentation style based on user interaction patterns and response times.

Compared to their generic adaptive approach, my system specifically integrates sports training with therapeutic content generation using natural language processing. Their system focused on academic learning, while mine addresses physical activity and tennis skill development. My approach is superior because it combines AI-powered personalization with sports therapy, creating magical narratives that specifically engage children in physical activity rather than passive screen-based learning, addressing both fitness and therapeutic needs simultaneously.

This study examined gamification techniques in digital sports training platforms, comparing engagement metrics across different reward systems and progression mechanisms [12]. Their platform used point-based systems and achievement badges to motivate young athletes in various sports activities.

Their system used generic gamification without personalization, while my application generates individualized magical narratives tailored to each child's interests and needs. They relied on standard reward mechanics, whereas my system creates unique adventure stories that transform exercises into personal quests. My approach is more effective because it addresses the root cause of engagement through personalized storytelling rather than superficial point systems, creating deeper emotional connections and sustained motivation through meaningful, customized content rather than generic rewards.

This research investigated AI-driven personalization in health apps for children, focusing on content adaptation based on age, learning preferences, and medical conditions [13]. Their system used collaborative filtering and content-based recommendations to customize exercise routines and educational materials.

While their system provided general health content personalization, my application specifically targets tennis training with narrative-driven engagement. Their approach used data mining for recommendations, but my system employs generative AI to create unique content for each user session. My methodology is superior because it generates fresh, magical narratives that prevent content staleness and maintain engagement through storytelling, whereas their recommendation-based approach eventually exhausts content variety, leading to reduced long-term user engagement and motivation.

6. CONCLUSIONS

The current tennis training application has several limitations that present opportunities for future enhancement. The primary limitation is the dependency on internet connectivity for AI content generation and Firebase synchronization, which restricts access in areas with poor network coverage [14]. Additionally, the application currently lacks integration with physical tennis equipment or motion tracking capabilities, limiting its ability to provide real-time form correction and skill assessment.

Given more development time, I would focus on implementing computer vision integration for pose estimation and movement analysis, allowing the app to provide feedback on actual tennis techniques. This would require adding camera-based motion tracking and machine learning models trained on tennis movements [15]. I would also develop offline functionality with pre-generated content libraries and local progress tracking.

Future expansion plans include integrating with wearable devices for biometric monitoring, developing multiplayer features for virtual tennis matches, and creating coach dashboard interfaces for professional oversight. Additionally, expanding beyond tennis to other sports using the same personalization framework would increase the application's market reach.

If starting over, I would implement a modular architecture from the beginning to support multiple sports, invest in more comprehensive user testing with diverse autism spectrum needs, and design the system with offline-first capabilities. I would also establish partnerships with tennis professionals earlier in development to ensure exercise content meets professional standards and therapeutic requirements.

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