

AI-Based Automated STEM Evaluation System - Requirements Document

1. Executive Summary

The AI-Based Automated STEM Evaluation System is a comprehensive platform designed to assess, evaluate, and provide feedback on student STEM capabilities, with a specific focus on VEX robotics (IQ and V5) education environments. The system leverages AI-powered analysis to provide automated feedback, benchmarking, and personalized recommendations for students, coaches, and parents.

2. Project Overview

2.1 Purpose

To create an intelligent evaluation system that:

- Assesses student STEM understanding through dynamic questioning
- Provides automated feedback on robotics projects and engineering notebooks
- Evaluates programming techniques and suggests optimizations
- Generates comprehensive reports and benchmarks
- Facilitates collaborative learning through a forum-style platform

2.2 Scope

- **In Scope:** STEM assessment, VEX robotics evaluation, programming analysis, reporting, RBAC, forum functionality
- **Out of Scope:** Live robotics simulation, hardware integration, third-party LMS integration (Phase 1)

2.3 Target Users

- **Students:** K-12 students participating in VEX robotics programs
- **Coaches:** Instructors managing classes and teams
- **Parents:** Guardians monitoring student progress
- **Administrators:** System administrators managing the platform

3. Functional Requirements

3.1 Assessment System (FR-AS)

FR-AS-01: Dynamic Question Generation

- **Priority:** Critical
- **Description:** System shall generate adaptive STEM questions based on student level and performance
- **Acceptance Criteria:**
 - Questions adapt to student responses in real-time
 - Support multiple question types: multiple choice, short answer, coding challenges

- Question difficulty adjusts based on correctness of previous answers
- Maintain question pool versioning for consistency

FR-AS-02: VEX Robotics Competition Support

- **Priority:** Critical
- **Description:** Support both VEX IQ and VEX V5 platforms
- **Acceptance Criteria:**
 - Identify robot components in uploaded images
 - Recognize VEX-specific programming patterns (VEXcode, PROS, Robot Mesh)
 - Apply competition-specific evaluation criteria (design, programming, teamwork)

FR-AS-03: Multi-Modal Content Upload

- **Priority:** Critical
- **Description:** Students shall upload images, documents, and code files
- **Acceptance Criteria:**
 - Support image formats: JPG, PNG, HEIC (max 10MB per file)
 - Support document formats: PDF, DOCX (engineering notebooks)
 - Support code files: Python, C++, Blocks (VEXcode)
 - Support up to 20 files per submission
 - Generate thumbnails for images

FR-AS-04: Automated Feedback Generation

- **Priority:** Critical
- **Description:** AI shall analyze submissions and provide constructive feedback
- **Acceptance Criteria:**
 - Feedback provided within 5 minutes of submission
 - Feedback includes specific improvement suggestions
 - Feedback tone is encouraging and educational
 - Feedback references specific submission elements
 - Include confidence scores for AI-generated feedback

FR-AS-05: Engineering Notebook Evaluation

- **Priority:** High
- **Description:** Analyze engineering notebooks for completeness and quality
- **Acceptance Criteria:**
 - Extract text from PDF/DOCX documents
 - Evaluate against VEX notebook rubric criteria
 - Identify missing sections (design process, testing, reflection)
 - Check for proper documentation practices
 - Generate rubric-based scoring

3.2 Programming Evaluation (FR-PE)

FR-PE-01: Code Analysis

- **Priority:** Critical
- **Description:** Evaluate programming submissions for correctness and efficiency
- **Acceptance Criteria:**
 - Support Python, C++, and VEXcode Blocks
 - Detect syntax errors and logical issues
 - Identify common anti-patterns
 - Calculate code complexity metrics

FR-PE-02: Optimization Suggestions

- **Priority:** High
- **Description:** Provide automated code optimization recommendations
- **Acceptance Criteria:**
 - Suggest performance improvements
 - Recommend better algorithmic approaches
 - Identify redundant code
 - Provide before/after code examples
 - Explain reasoning behind each suggestion

FR-PE-03: Best Practices Validation

- **Priority:** Medium
- **Description:** Check code against VEX and general programming best practices
- **Acceptance Criteria:**
 - Validate proper use of sensors and motors
 - Check for proper error handling
 - Verify commenting and documentation
 - Assess code organization and structure

3.3 Reporting and Benchmarking (FR-RB)

FR-RB-01: Individual Student Reports

- **Priority:** High
- **Description:** Generate comprehensive reports for each student
- **Acceptance Criteria:**
 - Display STEM capability scores across domains (programming, engineering, problem-solving)
 - Show progress over time with trend charts
 - Compare performance to personal historical data
 - Include AI-generated insights and recommendations

FR-RB-02: Benchmarking System

- **Priority:** High
- **Description:** Compare student performance against cohorts
- **Acceptance Criteria:**
 - Calculate percentile rankings within class/grade/organization
 - Display standard deviation from mean performance
 - Generate anonymized comparison charts
 - Define performance levels (Beginner, Intermediate, Advanced, Expert)
 - Ensure FERPA compliance in benchmark displays

FR-RB-03: Parent Reports

- **Priority:** Medium
- **Description:** Provide parent-friendly summary reports
- **Acceptance Criteria:**
 - Simplified language suitable for non-technical parents
 - Highlight strengths and growth areas
 - Include actionable recommendations
 - Display progress milestones
 - Option to export as PDF

FR-RB-04: Coach Analytics Dashboard

- **Priority:** High
- **Description:** Provide class-level analytics for coaches
- **Acceptance Criteria:**
 - View aggregate class performance
 - Identify struggling students requiring intervention
 - Track submission rates and engagement
 - Export class reports
 - Filter and sort by various metrics

3.4 User Management and RBAC (FR-UM)

FR-UM-01: Centralized Authentication

- **Priority:** Critical
- **Description:** Single sign-on system for all users
- **Acceptance Criteria:**
 - Email/password authentication
 - Support for Google OAuth 2.0
 - Password reset functionality
 - Session management with secure tokens
 - Account lockout after failed attempts

FR-UM-02: Role-Based Access Control

- **Priority:** Critical
- **Description:** Implement four-tier RBAC system
- **Acceptance Criteria:**
 - **Student Role:** View own submissions, reports, forum posts
 - **Parent Role:** View child’s data only (multi-child support)
 - **Coach Role:** View/manage students in assigned classes
 - **Admin Role:** Full system access, user management
 - Role changes take effect immediately

FR-UM-03: Class and Team Management

- **Priority:** High
- **Description:** Organize students into classes and teams
- **Acceptance Criteria:**
 - Coaches can create and manage classes
 - Students can be assigned to multiple classes
 - Support for VEX team structure (2-6 students per team)
 - Invite code system for class enrollment
 - Bulk student import via CSV

FR-UM-04: Parent-Student Linking

- **Priority:** High
- **Description:** Secure association between parent and student accounts
- **Acceptance Criteria:**
 - Parents can link multiple students
 - Require student approval for linkage
 - Parents can unlink students
 - Audit log for linkage changes

3.5 Forum and Collaboration (FR-FC)

FR-FC-01: Discussion Board

- **Priority:** Medium
- **Description:** Reddit-style forum for STEM discussions
- **Acceptance Criteria:**
 - Create posts with title, description, and optional media
 - Support threaded comments (up to 5 levels deep)
 - Upvote/downvote system for posts and comments
 - Sort by: Hot, New, Top, Controversial
 - Tag posts with topics (robotics, programming, mechanical design, etc.)

FR-FC-02: Question/Answer System

- **Priority:** Medium

- **Description:** Facilitate student questions and coach/peer answers
- **Acceptance Criteria:**
 - Mark questions as “Answered”
 - Accept best answer designation
 - Notify coaches of unanswered questions
 - Search forum by keywords
 - Filter by answered/unanswered status

FR-FC-03: Content Moderation

- **Priority:** High
- **Description:** Ensure appropriate forum content
- **Acceptance Criteria:**
 - Profanity filter
 - Report inappropriate content button
 - Coach/Admin moderation queue
 - Ability to edit/delete posts and comments
 - User suspension capability

FR-FC-04: Notifications

- **Priority:** Medium
- **Description:** Notify users of forum activity
- **Acceptance Criteria:**
 - Email notifications for replies (configurable)
 - In-app notification center
 - Notify on: replies, mentions, best answer selection
 - Digest mode for daily summaries

4. Non-Functional Requirements

4.1 Performance (NFR-P)

NFR-P-01: Response Time

- API responses: < 200ms for 95% of requests
- Page load time: < 2 seconds
- AI feedback generation: < 5 minutes
- Concurrent users: Support 1,000 simultaneous users

NFR-P-02: Scalability

- Horizontal scaling for frontend and middleware
- Handle 10,000+ active students
- Process 500+ submissions per hour during peak times

NFR-P-03: Availability

- 99.5% uptime SLA
- Scheduled maintenance windows announced 7 days in advance
- Maximum unplanned downtime: 4 hours/month

4.2 Security (NFR-S)

NFR-S-01: Data Protection

- Encryption at rest (AES-256)
- Encryption in transit (TLS 1.3)
- PII data encrypted in database
- Regular security audits quarterly

NFR-S-02: Compliance

- FERPA compliant for educational records
- COPPA compliant for users under 13
- GDPR ready for international expansion
- SOC 2 Type II compliance target

NFR-S-03: Authentication Security

- Multi-factor authentication option
- Password complexity requirements
- Session timeout after 2 hours of inactivity
- Audit logging for all access and changes

4.3 Usability (NFR-U)

NFR-U-01: Accessibility

- WCAG 2.1 AA compliance
- Screen reader compatible
- Keyboard navigation support
- High contrast mode

NFR-U-02: Browser Support

- Chrome (last 2 versions)
- Firefox (last 2 versions)
- Safari (last 2 versions)
- Edge (last 2 versions)
- Mobile responsive design

NFR-U-03: Internationalization

- Support for English (Phase 1)
- Architecture supports future localization
- UTC time with user timezone conversion
- Unicode character support

4.4 Maintainability (NFR-M)

NFR-M-01: Code Quality

- 80%+ unit test coverage
- Automated CI/CD pipeline
- Code review required for all changes
- Linting and formatting standards enforced

NFR-M-02: Documentation

- API documentation (OpenAPI 3.0)
- Architecture decision records
- Deployment runbooks
- User documentation and tutorials

NFR-M-03: Monitoring

- Application performance monitoring
- Error tracking and alerting
- Usage analytics
- AI API cost tracking

4.5 AI and ML Requirements (NFR-AI)

NFR-AI-01: AI Model Management

- Use Google Vertex AI API
- Implement prompt caching for cost optimization
- Support multiple models (Gemini Pro, Gemini Pro Vision)
- Model version tracking and rollback capability

NFR-AI-02: AI Quality

- Feedback relevance score: > 85%
- False positive rate for code issues: < 10%
- Response consistency across similar submissions
- Regular evaluation against human expert annotations

NFR-AI-03: Cost Management

- Implement request rate limiting
- Cache frequent prompts for 24 hours
- Monitor per-user AI usage
- Set budget alerts and caps

5. Technical Constraints

5.1 Technology Stack

- **Frontend:** Next.js 14+ (React 18+, TypeScript)
- **Middleware:** Go 1.21+ (Gin or Echo framework)
- **Database:** PostgreSQL 15+ (primary), Redis (caching)
- **AI Platform:** Google Vertex AI
- **Storage:** Google Cloud Storage
- **Hosting:** Google Cloud Platform

5.2 Integration Requirements

- RESTful API architecture
- JWT-based authentication
- WebSocket support for real-time notifications
- Webhook support for async AI responses

5.3 Development Constraints

- Git-based version control (GitHub)
- Containerized deployment (Docker)
- Infrastructure as Code (Terraform)
- Automated testing in CI/CD

6. Assumptions and Dependencies

6.1 Assumptions

- Users have reliable internet access (minimum 3 Mbps)
- Students have access to devices with cameras for photo uploads
- Coaches are willing to adopt new evaluation methods
- VEX competition rules remain relatively stable

6.2 Dependencies

- Google Vertex AI API availability and pricing
- Google Cloud Platform services
- Third-party authentication providers (Google OAuth)
- VEX competition documentation and rubrics

7. Success Criteria

7.1 User Adoption

- 100+ students onboarded in first 3 months
- 80%+ weekly active user rate among enrolled students
- 90%+ user satisfaction score

7.2 System Performance

- Meet all NFR performance targets
- < 0.1% error rate in production
- Zero critical security vulnerabilities

7.3 Educational Impact

- Students show measurable improvement in STEM assessments
- Coaches report time savings in evaluation (target: 50%)
- Positive feedback from parents on communication and transparency

8. Out of Scope (Phase 1)

- Mobile native applications (iOS/Android)
- Integration with third-party LMS (Canvas, Schoology)
- Live video analysis of robot performance
- Hardware integration with VEX brain
- Real-time collaborative code editing
- Automated tournament registration
- Payment processing for premium features
- Advanced gamification features

9. Future Enhancements (Phase 2+)

- AI-powered tutoring chatbot
- Peer code review platform
- Virtual robotics simulation integration
- Competition bracket management
- Team collaboration tools
- Portfolio builder for college applications
- Skills certification system
- Industry partner connections

10. Glossary

- **VEX IQ:** Entry-level robotics platform for elementary and middle school
- **VEX V5:** Advanced robotics platform for middle and high school
- **Engineering Notebook:** Documentation of design process and team decisions

- **STEM:** Science, Technology, Engineering, and Mathematics
- **RBAC:** Role-Based Access Control
- **FERPA:** Family Educational Rights and Privacy Act
- **COPPA:** Children’s Online Privacy Protection Act

11. Approval

This requirements document must be reviewed and approved by: - Project Sponsor - Technical Lead - Product Manager - Educational Advisor/Coach Representative - Security Officer

Document Version: 1.0 **Last Updated:** 2025-10-18 **Status:** Draft for Review