

# AI-Powered Adaptive Learning Assessment & Practice Tool

## Design Specification Document

### 1. Adaptive Assessment Logic

#### Dynamic Difficulty Adjustment Algorithm

The assessment employs a **Modified Item Response Theory (IRT)** combined with a **Bayesian Knowledge Tracing** model to dynamically adjust difficulty.

#### Initial Difficulty Level

- Starting Point:** Medium difficulty (Level 3 on a 5-point scale)
- Calibration Phase:** First 3 questions establish baseline ability
- Subject-Specific Initialization:** Based on historical data or teacher input

#### Difficulty Adjustment Criteria

##### Upward Adjustment (Increase Difficulty)

- 3 consecutive correct answers → +1 level
- Response time < 50% of allocated time with correct answer → +0.5 level
- Confidence rating ≥ 80% with correct answer → +0.25 level

##### Downward Adjustment (Decrease Difficulty)

- 2 consecutive incorrect answers → -1 level
- Response time > 150% allocated time → -0.5 level
- Multiple hint requests → -0.25 level per hint

#### Stabilization Rules

- Maintain current level if accuracy is between 60-75%
- Lock difficulty for 5 questions after major adjustment (±2 levels)
- Implement "challenge questions" every 10th question to test upper bounds

#### Difficulty Levels Framework

Level	Description	Characteristics
1	Foundational	Basic recall, single-step problems
2	Developing	Two-step problems, simple application

Level	Description	Characteristics
3	Intermediate	Multi-step reasoning, pattern recognition
4	Advanced	Complex analysis, abstract thinking
5	Expert	Novel problems, creative synthesis

## 2. Learning Gap Identification

### Four Fundamentals Assessment Framework

#### A. Listening (Comprehension & Processing)

Assessment Methods:

- Audio-based questions with varying speeds
- Video lectures with comprehension checks
- Verbal instructions for problem-solving

Sample Questions:

- "Listen to this explanation of percentages and identify the key formula"
- "After hearing the problem statement, select the correct approach"

Gap Indicators:

- Repeatedly asking to replay audio (> 2 times)
- Incorrect answers on audio-only questions vs text-based
- Response time delays after audio input

#### B. Grasping (Understanding & Conceptualization)

Assessment Methods:

- Concept mapping exercises
- "Explain in your own words" prompts
- Analogy completion tasks

Sample Questions:

- "Which diagram best represents the relationship between speed, distance, and time?"
- "Complete the analogy: Percentage is to 100 as probability is to \_\_\_\_"

Gap Indicators:

- Inability to transfer concepts across contexts
- Confusion between similar concepts
- Pattern: Memorization without understanding

### **C. Retention (Memory & Recall)**

#### **Assessment Methods:**

- Spaced repetition assessments
- Delayed recall tests (24hr, 7-day, 30-day)
- Formula and fact retrieval exercises

#### **Sample Questions:**

- "Recall the formula for compound interest you learned last week"
- "List the steps for solving a quadratic equation"

#### **Gap Indicators:**

- Steep forgetting curve (>40% drop in 24 hours)
- Inconsistent recall of previously mastered content
- Dependency on visual cues for recall

### **D. Application (Problem-Solving & Transfer)**

#### **Assessment Methods:**

- Real-world scenario problems
- Cross-domain application tasks
- Novel problem variations

#### **Sample Questions:**

- "Use percentage concepts to solve this profit-loss scenario"
- "Apply logical reasoning to debug this argument"

#### **Gap Indicators:**

- Success in practice but failure in new contexts
- Inability to combine multiple concepts
- Over-reliance on example templates

# Severity Classification

Severity	Score Range	Intervention Priority
Critical	<40%	Immediate, intensive support
Moderate	40-60%	Targeted practice, regular monitoring
Minor	60-75%	Supplementary exercises
None	>75%	Enrichment opportunities

## 3. Personalized Practice Content Generation

### AI Content Generation Engine

#### Content Types by Learning Gap

##### For Listening Gaps:

- Progressive audio exercises (slow → normal → fast)
- Interactive podcasts with embedded questions
- Voice-guided problem walkthroughs

##### For Grasping Gaps:

- Visual concept maps with interactive elements
- Socratic questioning sequences
- Metaphor-based explanations

##### For Retention Gaps:

- **WaniKani-Inspired SRS System:**
  - Apprentice → Guru → Master → Enlightened → Burned stages
  - Radicals → Building blocks → Complete concepts
  - Mnemonics generator for formulas and facts
- **Anki-Method Integration:**
  - Customizable spaced repetition intervals
  - Active recall with immediate feedback
  - Cloze deletion for key concepts

##### For Application Gaps:

- Scaffolded problem sets (guided → semi-guided → independent)
- Real-world case studies

- Gamified challenges with increasing complexity

## Difficulty Calibration for Practice

$\text{Practice Difficulty} = \text{Base Level} + (\text{Performance Factor} \times 0.3) + (\text{Engagement Factor} \times 0.2)$

Where:

- Base Level = Identified gap severity
- Performance Factor = Recent success rate
- Engagement Factor = Time spent + completion rate

## Content Generation Examples

### Quantitative Aptitude:

- Dynamic word problems with variable parameters
- Step-by-step solution builders
- Visual representation tools (graphs, charts)

### Logical Reasoning:

- Pattern sequence generators
- Syllogism builders with varying complexity
- Critical thinking scenarios

### Verbal Ability:

- Context-based vocabulary exercises
- Reading speed optimization drills
- Comprehension passage difficulty scaling

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## 4. Flexible Practice Modes

### Student Interface Design

#### Mode Selection Dashboard

PRACTICE MODE SELECTION

Chapter Practice

Select specific chapters

Mixed Practice

Balanced mix from all topics

Targeted Practice

Focus on your weak areas

Quick Challenge

5-minute timed sessions

Difficulty: 

Intermediate

[Adjust Difficulty Slider]

Mixed Questions Algorithm

Balanced Distribution Logic:

- 30% from weakest topic
- 25% from second weakest
- 20% from average performance topics
- 15% from strong topics (retention)
- 10% challenge questions (stretch)

Question Selection Criteria:

- Recency (not repeated within 10 questions)
  - Diversity (different question types)
  - Progressive difficulty within session
  - Time allocation balance
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## 5. Diagnostic Reports

### Student Report Dashboard



TOP AREAS FOR IMPROVEMENT

1. Formula retention (Quant)

2. Audio problem comprehension

3. Pattern recognition (LR)

[View Detailed Analysis]

### Teacher Dashboard



## Parent Report (Simplified)

### Your Child's Learning Journey

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#### ✓ Strengths:

- Excellent problem-solving skills
- Good conceptual understanding

#### ⚠ Areas for Support:

- Needs help remembering formulas
- Practice listening to math problems

#### 📊 This Week's Progress:

- Completed 45 practice sessions
- Improved retention by 12%
- Mastered 3 new concepts

#### 💡 Recommended Actions:

- Review flashcards together daily
- Use audio learning for 10 min/day

## 6. Sample User Journey: Sanga's Experience

### Day 1: Initial Assessment

#### Step 1: Onboarding

- Sanga logs in, sees friendly interface
- Brief tutorial on navigation
- Selects "Quantitative Aptitude" for assessment

#### Step 2: Adaptive Testing

- Q1 (Level 3): Percentage problem - Correct (slow)
- Q2 (Level 3): Ratio problem - Incorrect
- Q3 (Level 2): Basic arithmetic - Correct
- System identifies pattern: Good application, poor retention

#### Step 3: Immediate Feedback



- "Sanga, you're great at solving problems! Let's work on remembering formulas better."
- Prescribes memory palace technique
- Assigns first SRS card deck

## Day 7: Targeted Practice

### Personalized Session:

#### Today's Focus: Formula Retention

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1. Warm-up: Recall yesterday's formulas (SRS)
2. New concept: Compound interest
3. Mnemonic creation activity
4. Application practice with formula hints
5. Cool-down: Quick recall quiz

### Adaptive Response:

- Sanga struggles with recall → System provides visual mnemonics
- Succeeds with hints → Gradually reduces support
- Shows improvement → Unlocks "Memory Master" badge

## Day 30: Progress Review

### Comprehensive Report:

- Retention improved from 58% to 74%
  - Formula recall time decreased by 40%
  - Completed 89% of assigned practices
  - Ready for next difficulty level
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## 7. System Architecture

### Technical Stack

#### Backend Architecture



## AI Algorithms

### 1. Adaptive Assessment:

- **Algorithm:** Modified IRT with 3-parameter logistic model
- **Implementation:** Real-time ability estimation using Maximum Likelihood Estimation

### 2. Learning Gap Detection:

- **Algorithm:** Ensemble of Random Forest + Neural Network
- **Features:** Response patterns, time data, hint usage, error types

### 3. Content Generation:

- **Algorithm:** GPT-based fine-tuned model for question generation
- **Template System:** Rule-based variations for consistent quality

### 4. Spaced Repetition:

- **Algorithm:** Modified SM2 (SuperMemo) with personal adjustment factors

- **Formula:**

Next Review = Previous Interval × (2.5 × Performance Factor × Personal Modifier)

## Data Storage Schema

### User Progress Table:

```
sql

CREATE TABLE user_progress (
  user_id UUID PRIMARY KEY,
  fundamental_scores JSONB,
  learning_history JSONB[],
  srs_cards JSONB,
  last_assessment TIMESTAMP,
  adaptive_parameters JSONB
);
```

### Question Bank Structure:

```
json

{
  "question_id": "QA_001",
  "topic": "Quantitative Aptitude",
  "subtopic": "Percentages",
  "difficulty": 3,
  "fundamentals": ["grasping", "application"],
  "variants": [],
  "performance_stats": {},
  "mnemonics": []
}
```

## Frontend Technologies

- **Framework:** React/Next.js for web, React Native for mobile
- **State Management:** Redux Toolkit with RTK Query
- **UI Components:** Material-UI or Ant Design
- **Visualization:** D3.js for progress charts
- **Real-time Updates:** WebSocket for live feedback

## Security & Privacy

- End-to-end encryption for sensitive data

- COPPA/GDPR compliance for minor's data
  - Role-based access control (Student/Teacher/Parent/Admin)
  - Regular security audits and penetration testing
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## Integration of WaniKani & Anki Methods

### WaniKani-Inspired Features

#### 1. Radical System for Math:

- Break complex formulas into "radicals" (basic components)
- Build from simple to complex
- Visual mnemonics for each radical

#### Example:

Compound Interest Formula Breakdown:

Radical 1: Principal (P) - "The seed money"

Radical 2: Rate (r) - "The growth factor"

Radical 3: Time (t) - "The patience period"

Kanji:  $A = P(1 + r)^t$  - "Seeds grow exponentially with patience"

#### 2. Level Progression System:

- 60 levels of mastery across topics
- Unlock new concepts after mastering prerequisites
- Celebration milestones every 10 levels

### Anki-Inspired Features

#### 1. Custom Card Decks:

- Pre-made decks for each topic
- User-generated cards with community sharing
- Image occlusion for diagrams

#### 2. Review Scheduling:

Initial Learning: 10 min → 1 day → 3 days → 7 days → 14 days → 30 days

**Lapse Handling:**

- First lapse: Reset to 1 day
- Second lapse: Add extra practice step
- Third lapse: Flag for teacher intervention

### 3. Active Recall Techniques:

- Cloze deletions for formulas
- Reverse cards (answer → question)
- Type-in answers for maximum retention

## Implementation for Core Topics

### Quantitative Aptitude:

- Formula cards with visual representations
- Problem-solving process cards
- Shortcut technique cards

### Logical Reasoning:

- Pattern recognition cards
- Logical operator cards
- Argument structure templates

### Verbal Ability:

- Vocabulary with context sentences
- Root word analysis cards
- Reading strategy cards

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## Success Metrics & KPIs

1. **Learning Efficiency:** 30% reduction in time to mastery
2. **Retention Rate:** 85% retention after 30 days
3. **Engagement:** 70% daily active users
4. **Gap Closure:** 50% improvement in identified weak areas within 60 days
5. **User Satisfaction:** NPS score > 70

## Conclusion

This adaptive learning platform combines cutting-edge AI with proven learning methodologies to create a truly personalized educational experience. By identifying specific gaps across the four fundamentals and leveraging techniques from successful platforms like WaniKani and Anki, students receive targeted support that addresses their unique learning needs while maintaining engagement through gamification and progressive challenges.