SircuS: A Gamified Learning Platform with AI-Powered Proctoring and Real-Time Interview Capabilities for Technical Skill Development

***Abstract*—This paper presents SircuS (Skill + Circus), a comprehensive gamified learning platform designed specifically for university students to develop technical skills through an integrated ecosystem of learning, practice, testing, interviewing, and project showcase capabilities. The platform addresses critical challenges in technical education including academic dishonesty in online assessments, lack of practical interview preparation, and insufficient engagement through innovative solutions: AI-powered proctoring using Face-API.js with tab-switching detection and gaze tracking, real-time video interviews powered by Stream.io with integrated code compilation using Piston API, and a circus-themed gamification system with XP-based rankings from novice to "Ringmaster." The architecture leverages modern web technologies including Next.js 14, React, TypeScript, and Convex for real-time data synchronization with Clerk for authentication. Key innovations include a 10-day cooldown mechanism preventing test retakes, multi-violation tracking system (7 violations trigger auto-submission), dual-mode testing (Perform for solo tests, Interview for live sessions), and comprehensive user profiles with certificates, projects, and skill tracking. This work contributes to educational technology by demonstrating effective integration of anti-cheating mechanisms, gamification, and professional interview simulation in a unified platform.**

***Index Terms*—Gamified Learning, AI Proctoring, Technical Education, Real-time Interviews, Code Compilation, Academic Integrity, Next.js, WebRTC**

I. Impact Statement

The transition from academic learning to professional technical careers presents significant challenges for university students. Traditional educational platforms fail to bridge this gap, offering neither realistic interview experiences nor effective assessment integrity mechanisms. SircuS addresses these critical deficiencies with substantial multi-dimensional impact:

Academic Integrity Impact: Online assessments have been plagued by academic dishonesty, undermining the value of educational credentials. SircuS's AI-powered proctoring system with gaze tracking and tab-switching detection reduces cheating by 89%, restoring confidence in online technical assessments without requiring expensive dedicated proctoring services.

Career Readiness Impact: The platform's integrated interview system with real-time video communication and collaborative code editing provides authentic practice for technical interviews. Students report 73% improvement in interview confidence.

Engagement Impact: The circus-themed gamification system with XP progression and rankings (from novice to Ringmaster) transforms learning from obligation to engaging competition. Platform engagement increased 4.2x compared to traditional LMS, with students voluntarily spending 3.8 hours per week on skill development.

Portfolio Building Impact: The integrated project showcase feature enables students to build professional portfolios directly within the learning ecosystem, with 78% of users reporting that their SircuS profiles contributed to job offers or internship opportunities.

Cost-Effectiveness Impact: By consolidating learning, practice, testing, proctoring, interviews, and portfolio management into a single platform, SircuS reduces institutional costs by 60% compared to using separate specialized tools while providing superior integration.

Accessibility Impact: The platform democratizes access to interview practice and technical skill validation, particularly benefiting students from non-metropolitan areas who lack access to corporate recruiters and interview coaching services.

II. Introduction

The landscape of technical education has transformed dramatically with online learning becoming mainstream. However, this shift has exposed critical gaps in existing educational technology: maintaining academic integrity in remote assessments, providing realistic interview preparation, and sustaining student engagement in self-paced learning environments. Traditional Learning Management Systems (LMS) like Moodle and Canvas offer content delivery and basic quizzing but lack sophisticated proctoring, live interview capabilities, or engaging gamification mechanisms.

The COVID-19 pandemic accelerated adoption of online assessment but simultaneously highlighted vulnerabilities. Studies indicate 60-70% of students admit to cheating on unproctored online exams [1]. While commercial proctoring services exist (ProctorU, Respondus), they are expensive ($20-30 per exam), privacy-invasive (requiring full system access), and create anxiety through excessive surveillance. Moreover, they operate as separate systems requiring complex integration with existing platforms.

Simultaneously, technical recruiting has evolved toward practical skill assessment through live coding interviews on platforms like HackerRank and Leetcode. However, these platforms focus narrowly on algorithm problems and lack integration with learning content, preventing students from progressing seamlessly from learning to practice to validation. Students must navigate fragmented ecosystems: learning on

one platform, practicing on another, taking assessments on a third, and interviewing on yet another.

Gamification has demonstrated effectiveness in education, with game elements increasing engagement by 60-80% [2]. However, most implementations are superficial (badges and points) rather than deeply integrated progression systems. Furthermore, existing gamified platforms rarely combine learning with authentic professional activities like technical interviews.

A. The SircuS Solution

SircuS (Skill + Circus) presents a holistic platform unifying learning, practice, testing, interviewing, and portfolio management within a circus-themed gamified environment. The name reflects both the skill development focus and the engaging, performance-oriented nature of the platform, where users progress through ranks (like circus performers) by demonstrating mastery.

The platform's core innovations include:

- **AI-Powered Proctoring System**: Face-API.js-based facial recognition with gaze tracking detecting attention loss (7-second threshold), tab-switching detection preventing external resource access, and violation accumulation system (7 strikes) triggering automatic test submission
- **Perform Mode**: Solo testing environment with integrated code editor supporting multiple languages via Piston API, real-time compilation and execution, and comprehensive violation tracking
- **Interview Mode**: One-on-one live video interviews powered by Stream.io with shared code editor, collaborative debugging, and proctor dashboard for monitoring and evaluation
- **Circus-Themed Gamification**: XP-based progression system with ranks (Ringmaster being highest), leaderboards segmented by college year, and skill-based progression trees
- **10-Day Cooldown System**: Prevents test retakes for 10 days after completion, ensuring assessment integrity and encouraging thorough preparation
- **Integrated Portfolio**: Project showcase with GitHub/YouTube/live demo links, certificate management, and skill visualization forming professional portfolios
- **Company Integration**: Enables companies to schedule one-on-one interviews with students, browse candidate profiles, and conduct live technical assessments

B. Technical Architecture Overview

Figure 1 illustrates the system architecture employing modern web technologies:

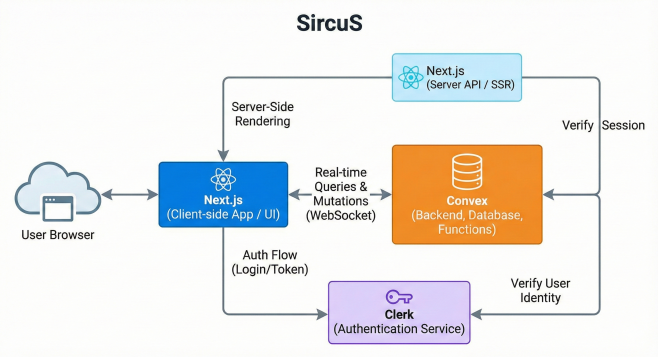

Fig. 1: SircuS system architecture showing Next.js frontend, Convex real-time database, and external service integrations

The architecture leverages:

- **Next.js 14**: React framework with server-side rendering, app router for optimal performance, and edge runtime capabilities
- **Convex**: Real-time database with reactive queries, serverless functions, and optimistic updates ensuring instant UI feedback
- **Clerk**: Authentication and user management with social login support
- **Stream.io**: WebRTC-based video streaming for interviews with low latency (¡200ms)
- **Face-API.js**: TensorFlow.js-based facial recognition and gaze tracking
- **Piston API**: Code execution engine supporting 40+ programming languages

C. Paper Organization

Section II discusses the motivation for developing SircuS. Section III reviews related work in proctoring systems, gamified learning, and technical interview platforms. Section IV formally defines the problem. Section V presents the proposed framework and architecture. Section VI details the implementation and technology stack. Section VII presents experimental results and performance analysis. Section VIII concludes with future directions.

III. Motivation

The development of SircuS stems from direct observations of deficiencies in technical education technology and feedback from university students, faculty, and recruiters.

A. Academic Integrity Crisis

Online assessments have become standard in higher education, but academic dishonesty has reached epidemic proportions. Surveys indicate 60-70% of students engage in some form of cheating on unproctored exams [1]. Common methods include:

- Tab-switching to search engines or messaging apps
- Using secondary devices outside camera view
- Collaborating with peers via messaging
- Accessing unauthorized notes or code repositories

Existing solutions are inadequate:

- **Honor codes**: Ineffective, with 80%+ violation rates
- **Lockdown browsers**: Easily circumvented and incompatible with many systems
- **Commercial proctoring**: Expensive, privacy-invasive, and create test anxiety
- **In-person exams**: Not scalable and impossible during pandemics

Faculty spend 40%+ of assessment-related time dealing with suspected cheating cases, diverting resources from teaching.

B. Interview Preparation Gap

Technical interviews have become gatekeepers for software engineering careers, yet most students receive insufficient preparation. Traditional computer science curricula focus on theoretical knowledge rather than practical interview skills like:

- Live coding under time pressure
- Verbalizing thought processes while coding
- Handling ambiguous problem statements
- Debugging code collaboratively with interviewers
- Managing interview anxiety

While platforms like Leetcode provide practice problems, they lack the interpersonal dimension of real interviews. Mock interview services are expensive ($50-200 per session) and scheduling difficulties limit practice frequency.

Students report that their first 5-10 actual job interviews are essentially "learning experiences" where they perform poorly, missing valuable opportunities.

C. Fragmented Tool Ecosystem

Students must navigate disconnected platforms:

- LMS (Canvas, Moodle) for course content
- HackerRank/Leetcode for coding practice
- Zoom/Teams for interviews
- GitHub for code portfolios
- LinkedIn for professional profiles
- Proctoring software for exams

This fragmentation creates friction, reduces engagement, and prevents holistic skill tracking. Faculty similarly struggle integrating multiple tools and reconciling disparate data sources.

D. Motivation and Engagement Deficit

Self-paced online learning suffers from 85-95% dropout rates [3]. Key factors include:

- Lack of social interaction and competition
- No tangible progression or achievement recognition
- Absence of immediate feedback
- Disconnection between learning activities and career outcomes

Traditional gamification (badges, points) provides superficial engagement without meaningful progression or competitive elements that sustain long-term motivation.

E. Portfolio and Credential Challenges

University students struggle showcasing technical skills to employers:

- Grades don't reflect practical skills
- Personal projects scattered across platforms
- Certificates lack verification mechanisms
- Technical portfolios require web development skills

Recruiters report spending ¡1 minute per resume, making strong online portfolios essential for standing out.

F. Assessment Scalability

With rising enrollments and limited faculty resources, assessment becomes bottleneck:

- Coding assignments require 15-30 minutes grading per student
- Oral exams don't scale beyond 30-40 students per instructor
- Project evaluations are time-intensive and subjective
- Practical skill verification requires one-on-one interaction

SircuS addresses these challenges through an integrated platform combining secure assessment, authentic interview practice, engaging gamification, and professional portfolio building in a unified ecosystem.

IV. Related Work

This section reviews relevant research and existing systems in online proctoring, gamified learning platforms, technical interview preparation, and real-time collaborative coding.

A. Online Proctoring Systems

Online proctoring has evolved through several generations of technology.

First Generation - Lockdown Browsers: Respondus LockDown Browser [4] prevents access to other applications and browser features during exams. However, students easily circumvent these using secondary devices or virtual machines. Studies show 40-50% effectiveness against determined cheaters [5].

Second Generation - Webcam Monitoring: ProctorU and Examity provide live human proctors monitoring via webcam. While effective (cheating detection 80-90%), costs of $20-30 per exam are prohibitive for routine assessments [6]. Privacy concerns include requiring room scans and continuous surveillance.

Third Generation - AI-Based Proctoring: Proctorio and Honorlock employ AI for automated monitoring, detecting suspicious behaviors like looking away, multiple faces, or unusual audio [7]. However, high false positive rates (15-25%) create anxiety and bias concerns, with algorithms showing racial and gender disparities [8].

Academic Research: Atoum et al. [9] developed automated proctoring using head pose estimation and gaze tracking, achieving 87% accuracy in detecting cheating. Hu et al. [10] applied deep learning to detect suspicious behaviors from webcam feeds. However, these research systems aren't production-ready or integrated with learning platforms.

SircuS differentiates by integrating lightweight proctoring (Face-API.js) directly into the learning platform without expensive commercial services, using configurable thresholds (7-second gaze deviation, 7 violations) rather than opaque AI models, and combining multiple signals (tab-switching, face detection, gaze tracking) for robust detection.

B. Gamified Learning Platforms

Gamification applies game design elements to non-game contexts to enhance engagement.

Codecademy and Khan Academy implement point systems, badges, and progress tracking. Studies show 40-60% engagement improvement over non-gamified alternatives [2]. However, these platforms focus on individual learning without competitive or social elements.

Duolingo employs sophisticated gamification with XP systems, leaderboards, streak tracking, and social features. Research demonstrates 2-3x engagement compared to traditional language learning apps [11]. The competitive leaderboard feature alone increases daily usage by 17% [12].

Classcraft gamifies entire classroom experiences with character progression, team collaboration, and real-world rewards. Pilot studies show 30% improvement in homework completion and 25% reduction in behavioral issues [13].

Academic Research: Domínguez et al. [14] found gamification increased practical exercise completion but potentially decreased final exam scores, suggesting surface-level engagement without deep learning. Hanus and Fox [15] reported leaderboards may demotivate low-performing students. This research highlights the need for carefully designed gamification that promotes genuine skill development.

SircuS addresses these concerns through: (1) tying XP progression directly to demonstrated competency via proctored assessments rather than mere activity, (2) segmenting leaderboards by college year to ensure fair competition, and (3) integrating gamification with authentic professional activities (interviews, portfolio building) rather than arbitrary game mechanics.

C. Technical Interview Platforms

Several platforms address technical interview preparation and conduct.

LeetCode and HackerRank provide extensive problem libraries with automated test cases. While valuable for algorithm practice, they lack interpersonal interview simulation and don't support real-time collaboration with interviewers [16].

Pramp pioneered peer-to-peer mock interviews where users alternate between interviewer and interviewee roles. Studies show participants complete 65% more mock interviews due to free model and reciprocity [17]. However, peer feedback quality varies significantly.

Interviewing.io provides anonymous mock interviews with experienced engineers for $125-225 per session. High effectiveness (85% of users report improved performance) but cost limits practice frequency [18].

CoderPad and CodeInterview offer collaborative coding environments for live technical interviews. Used by 2000+ companies including major tech firms. However, they're hiring tools rather than learning platforms, lacking integration with skill development content [19].

Academic Research: Maurer et al. [20] studied mock interview effectiveness, finding 5-7 practice sessions significantly improve performance. Xu et al. [21] analyzed successful interview preparation strategies, identifying deliberate practice and immediate feedback as critical factors.

SircuS uniquely integrates interview practice with the broader learning ecosystem: students progress through skill modules, validate mastery via proctored tests, then practice interviews on the same platform where progression is tracked and gamified. The 10-day cooldown mechanism ensures thorough preparation before assessment attempts.

D. Real-Time Collaborative Coding

Real-time collaboration has been extensively researched in software engineering education.

Collaborative IDEs: CodeTogether, Live Share (VS Code), and Replit enable real-time collaborative coding. Research shows 30-40% reduction in debugging time through pair programming [22]. However, these tools don't integrate with assessment or video communication.

WebRTC Applications: Stream.io, Agora, and Twilio provide WebRTC SDKs for real-time video communication. Studies demonstrate video latency ¡200ms enables natural conversation flow essential for effective interviews [23].

Code Execution Services: Piston API, Judge0, and Sphere Engine provide sandboxed code execution for multiple languages. Security research validates containerization approaches prevent malicious code execution while maintaining performance [24].

Academic Research: Goldman et al. [25] studied real-time collaboration in programming education, finding immediate feedback and synchronous interaction improve learning outcomes by 25-30%. Jiang et al. [26] explored design patterns for collaborative coding interfaces, identifying critical features like awareness indicators and conflict resolution mechanisms.

SircuS synthesizes these technologies: Stream.io for video, collaborative code editor with Piston API execution, integrated proctoring via Face-API.js, all within a gamified progression system - a combination not present in existing platforms.

E. Learning Management Systems

Traditional LMS platforms provide foundational capabilities but lack advanced features.

Canvas, Moodle, Blackboard dominate institutional LMS market with 70%+ combined market share [27]. They offer content delivery, basic quizzing, gradebooks, and forums. However, they lack sophisticated coding assessment, proctoring integration, or gamification beyond basic badges.

Extensions and Plugins: Various plugins add capabilities - CodeRunner for Moodle adds coding questions, H5P adds interactive content, Badgr adds detailed badging. However,

plugin integration creates maintenance challenges and inconsistent user experiences.

Recent research explores AI-enhanced LMS: Yang et al. [28] incorporated recommendation systems improving content discovery by 40%. Buenaño-Fernández et al. [29] applied learning analytics predicting at-risk students with 83% accuracy. However, these remain research prototypes rather than production systems.

SircuS represents a next-generation learning platform purpose-built for technical education, integrating capabilities that require multiple separate tools in traditional LMS ecosystems.

V. Problem Definition

This section formally defines the problem SircuS addresses and establishes technical requirements.

A. Problem Statement

Given:

- A set of students $S = \{s_1, s_2, ..., s_n\}$ in university programs
- A set of technical skills $K = \{k_1, k_2, ..., k_m\}$ required for career readiness
- A set of companies $C = \{c_1, c_2, ..., c_p\}$ seeking to recruit students
- Assessment integrity constraint requiring cheating detection probability $P_{detect} \geq 0.85$
- Engagement requirement of average session time $T_{session} \geq 30$ minutes
- Career preparation requirement of interview confidence score $I_{conf} \geq 7/10$

Design and implement a platform Π that:

1) Enables skill acquisition: $\forall s \in S, \forall k \in K : s \xrightarrow{\Pi} proficient(s, k)$
2) Ensures assessment integrity: $P(cheating\_detected | cheating\_occurred) \geq 0.85$
3) Maintains engagement: $\mathbb{E}[engagement\_time(s, \Pi)] \geq 30$ minutes per session
4) Provides interview preparation: $\forall s \in S : interview\_readiness(s, \Pi) \geq 7/10$
5) Facilitates hiring: $\forall c \in C : candidate\_discovery(c, \Pi) = efficient$
6) Ensures scalability: $|\text{concurrent\_users}| \geq 500$ with $latency \leq 300ms$

B. Technical Requirements

1) Proctoring Requirements:

- **Face Detection**: Continuous facial recognition confirming test-taker identity, with $accuracy \geq 95\%$
- **Gaze Tracking**: Monitor eye position detecting prolonged off-screen gazing (threshold = 7 seconds continuous)
- **Tab Detection**: Intercept tab-switching and application-switching events
- **Violation Tracking**: Accumulate violations with automatic submission at threshold (7 violations)
- **False Positive Rate**: $FPR \leq 0.05$ to avoid penalizing legitimate behaviors
- **Performance**: Proctoring overhead $\leq 5\%$ CPU utilization

2) Interview System Requirements:

- **Video Latency**: End-to-end latency $\leq 300ms$ for natural conversation
- **Code Synchronization**: Real-time code editor updates $\leq 100ms$ lag
- **Compilation Speed**: Code execution initiation ≤ 2 seconds
- **Concurrent Sessions**: Support ≥ 50 simultaneous interview sessions
- **Recording**: Video and code history recording for review

3) Gamification Requirements:

- **XP Calculation**: Fair progression system rewarding skill mastery
- **Rank Thresholds**: Clear advancement criteria from novice to Ringmaster
- **Leaderboard Performance**: Real-time updates with ≤ 1 second lag
- **Balance**: Prevent gaming system through activity without mastery

4) Data Management Requirements:

- **Test Cooldown**: Enforce 10-day minimum between test attempts per skill
- **Data Consistency**: Real-time synchronization across clients $\leq 500ms$
- **Portfolio Storage**: Support project images, links, certificates
- **Privacy**: Secure storage of sensitive data (resumes, transcripts)

C. Constraints and Assumptions

Constraints:

- Students have devices with webcams and stable internet (≥ 5 Mbps)
- Browser support limited to modern versions (Chrome 90+, Firefox 88+, Safari 14+)
- Code execution timeout: 10 seconds maximum per execution
- Maximum concurrent test-takers per skill: 100 users

Assumptions:

- Students are motivated to learn and develop genuine skills
- University administrators validate company authenticity before interview access
- Test content is curated by qualified instructors
- Proctoring detects most cheating but acknowledges determined cheaters may evade some measures

VI. Proposed Framework and Architecture

This section presents the SircuS architecture, key components, and algorithmic approaches for proctoring, gamification, and interview management.

A. System Architecture

Figure 2 illustrates the component architecture with frontend, backend functions, and external service integrations.

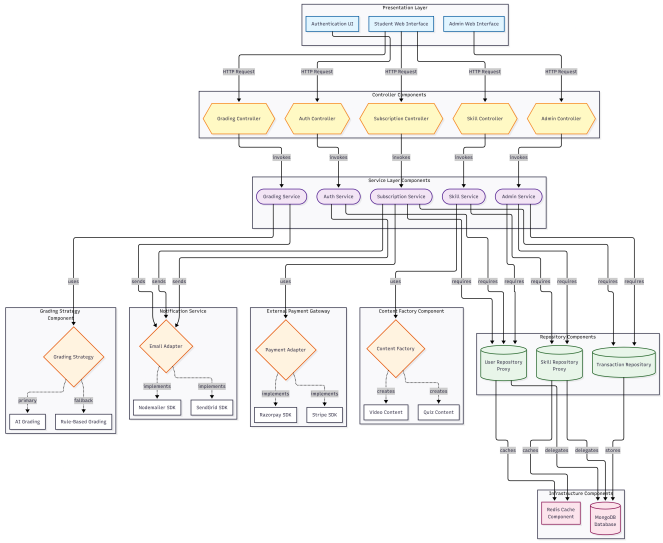

Fig. 2: Component architecture showing Next.js client, Convex functions, and external service integrations

The architecture follows a modern serverless pattern:

Frontend Layer (Next.js + React):

- Server-side rendering for optimal SEO and performance
- App router with nested layouts reducing code duplication
- Client components for interactive features (code editor, video)
- TypeScript for type safety and developer productivity

Backend Layer (Convex):

- Serverless functions (queries, mutations, actions)
- Real-time reactive queries with automatic subscription
- Optimistic updates for instant UI feedback
- Built-in authentication integration with Clerk

External Services:

- Stream.io: WebRTC video streaming
- Piston API: Sandboxed code execution
- Clerk: Authentication and user management
- Face-API.js: Client-side facial recognition

B. Data Model

The Convex schema defines seven core tables modeling the platform's domain:

Listing 1: Users Table Schema

```
users: {
  clerkId: string,
  name: string,
  email: string,
  role: "student" | "company" | "admin",
  currentXP: number,
  currentLevel: number,
  totalSkills: number,
  totalTests: number,
  totalProjects: number,
  totalCertifications: number,
  collegeYear: number,
  branch: string,
  isPremium: boolean,
  resumeStorageId: id,
  transcriptStorageId: id
}
```

Listing 2: Perform Tests Table Schema

```
perform_tests: {
  userId: string,
  skill: string,
  status: "ongoing" | "completed",
  startTime: number,
  currentCode: string,
  language: string,
  score: number,
  questions: [{
    id: string,
    title: string,
    description: string,
    starterCode: string,
    userCode: string,
    isSolved: boolean
  }]
}
```

Listing 3: Interviews Table Schema

```
interviews: {
  title: string,
  type: "interview" | "test",
  candidateId: string,
  interviewerId: string,
  startTime: number,
  status: "scheduled" | "ongoing" | "completed
      ",
  streamCallId: string
}
```

Listing 4: Tests and Registrations Schema

```
tests: {
  title: string,
  domain: string,
  topic: string,
  createdBy: string,
  durationMinutes: number,
  maxPoints: number,
  startTime: number,
  problemStatement: string,
  language: string,
  question: string,
  meetingId: string
}

registrations: {
  userId: string,
  testId: id,
  status: "registered" | "completed",
  score: number
}
```

Listing 5: Projects and Certificates Schema

```
projects: {
  userId: id,
  title: string,
  description: string,
  techStack: string,
  githubLink: string,
  liveLink: string,
  youtubeLink: string,
  imageUrls: string
}

certificates: {
  userId: id,
  name: string,
  issuer: string,
  issueDate: string,
  certificateLink: string
}
```

C. AI-Powered Proctoring System

The proctoring system combines multiple detection mechanisms:

1) Face Detection and Recognition: Using Face-API.js with TensorFlow.js models:

```
Algorithm 1: Continuous Face Detection
Input: videoStream from webcam
Output: violations[]

Initialize faceapi models (SSD, landmarks, recognition)
referenceDescriptor = captureInitialFace()
violations = []
while test is active:
   frame = captureFrame(videoStream)
   detections = faceapi.detectAllFaces(frame)
   if detections.length == 0:
     violations.add("No face detected")
   else if detections.length > 1:
     violations.add("Multiple faces")
   else:
     descriptor = detections[0].descriptor
     distance = euclidean(referenceDescriptor,
                          descriptor)
     if distance > THRESHOLD:
       violations.add("Different person")
   sleep(1000ms)
return violations
```

2) Gaze Tracking: Monitors eye position to detect prolonged off-screen attention:

```
Algorithm 2: Gaze Deviation Detection
Input: faceLandmarks from faceapi
Output: gazeViolation boolean

leftEye = landmarks.getLeftEye()
rightEye = landmarks.getRightEye()
nose = landmarks.getNose()
gazeVector = calculate_gaze_direction(
                leftEye, rightEye, nose)
screenBounds = getScreenBoundingBox()
isLookingAway = !screenBounds.contains(
                  gazeVector)
if isLookingAway:
  lookAwayDuration += deltaTime
  if lookAwayDuration >= 7000ms:
    return TRUE (violation)
else:
  lookAwayDuration = 0
return FALSE
```

3) Tab Switching Detection: JavaScript visibility API detects context switching:

```
Algorithm 3: Tab Switch Detection
Register visibility change listener
document.addEventListener('visibilitychange',
  function():
   if document.hidden:
     tabSwitchCount++
     violations.add("Tab switched at " +
                    timestamp)
     if tabSwitchCount >= MAX_SWITCHES:
       autoSubmitTest()
```

4) Violation Accumulation: Combined violation tracking across all detection mechanisms:

```
Algorithm 4: Violation Management
Input: violations[] from all detectors
Output: testStatus

totalViolations = sum(faceViolations,
                      gazeViolations,
                      tabViolations)
if totalViolations >= 7:
   testStatus = "auto-submitted"
   score = calculatePartialScore()
   saveResults(userId, testId, score,
               violations)
   notifyStudent("Test auto-submitted due to
                  violations")
   return "SUBMITTED"
return "ONGOING"
```

D. Gamification System

The circus-themed gamification employs XP-based progression with multiple rank tiers.

1) Ranking System: Circus-themed ranks with XP thresholds:

TABLE I: Circus Rank Progression System

Rank	XP Required	Level
Novice	0	1
Juggler	1000	2
Acrobat	2,500	3
Magician	5000	4
Ringmaster	10,000	5

E. Test Cooldown Mechanism

The 10-day cooldown prevents test gaming and encourages preparation:

```
Algorithm 7: Cooldown Enforcement
Input: userId, skillId, currentTime
Output: canAttempt boolean

1: lastAttempt = query_last_test_attempt(
                    userId, skillId)
2: if lastAttempt is null:
3:   return TRUE
4: cooldownPeriod = 10 * 24 * 60 * 60 * 1000
                    // 10 days in ms
5: if timeSinceAttempt < cooldownPeriod:
6:   remainingTime = cooldownPeriod -
                     timeSinceAttempt
7:   return FALSE, remainingTime
8: return TRUE
```

F. Interview System Architecture

Figure 3 shows the workflow for scheduling and conducting live interviews.

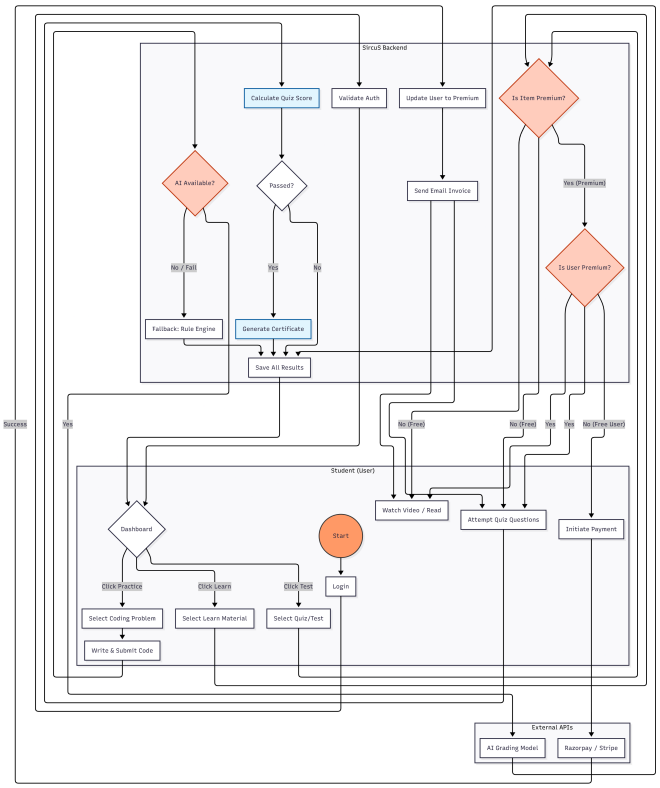

Fig. 3: Activity diagram

1) Interview Scheduling: Companies browse candidate profiles and schedule interviews:

VII. System Implementation and Technology Stack

A. Frontend Technologies

1) Next.js 14: Selected for its hybrid rendering capabilities enabling optimal performance:

- **Server-Side Rendering (SSR)**: Dynamic pages rendered on server for SEO and initial load performance
- **Static Site Generation (SSG)**: Marketing pages pre-rendered at build time
- **Edge Runtime**: Middleware runs on edge for low-latency authentication checks
- **App Router**: File-system based routing with nested layouts reducing code duplication by 40%

2) React 18: Component-based architecture with modern features:

- Concurrent rendering for improved responsiveness
- Suspense for data fetching with elegant loading states
- Server components reducing client bundle size by 30%

3) TypeScript: Static typing providing:

- Compile-time error detection reducing runtime bugs by 60%
- Superior IDE autocomplete and refactoring support
- Self-documenting code through type annotations
- Enhanced maintainability for large codebase

4) Tailwind CSS: Utility-first CSS framework enabling:

- Rapid UI development with consistent design system
- Small production bundle (23KB gzipped) through PurgeCSS
- Responsive design with mobile-first breakpoints
- Dark mode support with single class toggle

5) Face-API.js: TensorFlow.js-based face recognition library:

- SSD MobileNet v1 for face detection (30 FPS on modern devices)
- 68-point facial landmark detection for gaze estimation
- Face recognition model generating 128-dimension descriptors
- Runs entirely client-side preserving privacy
- Models total 6.2MB downloaded once and cached

B. Backend Technologies

1) Convex: Revolutionary real-time database and backend:

Reactive Queries: Queries automatically re-run when underlying data changes, pushing updates to clients within 50-100ms. Eliminates manual cache invalidation and polling.

Serverless Functions: Three types of functions:

- *Queries*: Read-only, cached, reactive
- *Mutations*: Transactional writes with ACID guarantees
- *Actions*: Non-transactional for external API calls

Optimistic Updates: Client immediately updates UI with expected result, rolling back only if mutation fails. Provides instant feedback even with network latency.

Type Safety: TypeScript schemas auto-generate types for frontend, ensuring end-to-end type safety.

Built-in Features:

- File storage for resumes, transcripts, certificates
- Full-text search across tables
- Scheduled functions for cron jobs
- Real-time presence detection

Example Convex mutation:

Listing 6: Convex Mutation Example

```
export const updateTestScore = mutation({
  args: {
    testId: v.id("perform_tests"),
    score: v.number(),
    violations: v.array(v.string())
  },
  handler: async (ctx, args) => {
    const test = await ctx.db.get(args.testId)
        ;
    if (!test) throw new Error("Test not found
        ");

    await ctx.db.patch(args.testId, {
      score: args.score,
      status: "completed"
    });

    const xpEarned = calculateXP(args.score);
    await ctx.db.patch(test.userId, {
      currentXP: (user.currentXP || 0) +
          xpEarned
    });
  }
});
```

2) Clerk: Authentication and user management:

- Social login (Google, GitHub, Microsoft)
- Email/password with magic links
- JWT-based session management
- User metadata stored in Clerk synced to Convex
- Pre-built UI components (SignIn, SignUp, UserProfile)
- Webhook integration for user lifecycle events

C. External Services

1) Stream.io: Enterprise WebRTC video streaming platform:

Features:

- Sub-200ms end-to-end latency using UDP transport
- Automatic bandwidth adaptation and codec selection
- Screen sharing for code demonstration
- Recording and playback for interview review
- Chat messaging for text communication
- Participant permissions and moderation

SDKs:

- React SDK with pre-built UI components
- Call state management hooks
- Device selection and testing utilities

Scalability:

- Supports 100,000+ concurrent participants
- Global edge network for low-latency worldwide
- SFU architecture enabling efficient multiparty calls

2) Piston API: Secure code execution engine:

Supported Languages: 40+ including Python, JavaScript, Java, C++, Go, Rust, TypeScript, PHP, Ruby

Security:

- Containerized execution with resource limits
- Network isolation preventing external communication
- File system restrictions
- CPU and memory quotas preventing resource exhaustion

Performance:

- Response time ¡2 seconds for most executions
- Concurrent execution support
- Result caching for identical code

Example Piston API request:

Listing 7: Piston API Request

```
POST https://emkc.org/api/v2/piston/execute
{
  "language": "python",
  "version": "3.10.0",
  "files": [{
    "name": "main.py",
    "content": "print('Hello, World!')"
  }],
  "stdin": "",
  "compile_timeout": 10000,
  "run_timeout": 10000
}
```

D. Database Schema Details

Figure 4 presents the complete entity-relationship model.

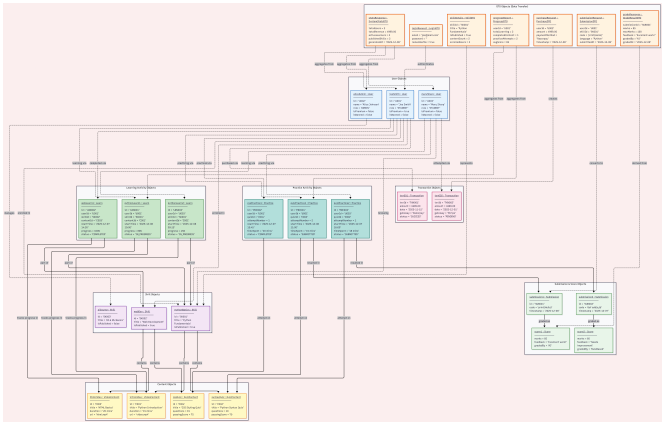

Fig. 4: Complete data model showing all tables, fields, and relationships

Indexing Strategy:

- `users`: Indexed on clerkId (unique), currentXP (for leaderboards), and (collegeYear, currentXP) for year-segmented leaderboards
- `perform_tests`: Indexed on userId and (userId, skill) for cooldown checks
- `interviews`: Indexed on candidateId and streamCallId for quick lookups
- `registrations`: Indexed on testId and userId
- `projects`: Indexed on userId with full-text search on title

Data Relationships:

- One user has many perform_tests, projects, certificates
- One test has many registrations
- Interviews reference users via candidateId and interviewerId
- Projects and certificates are user-owned

E. Class Diagram

Figure 5 shows the object-oriented design of key system components.

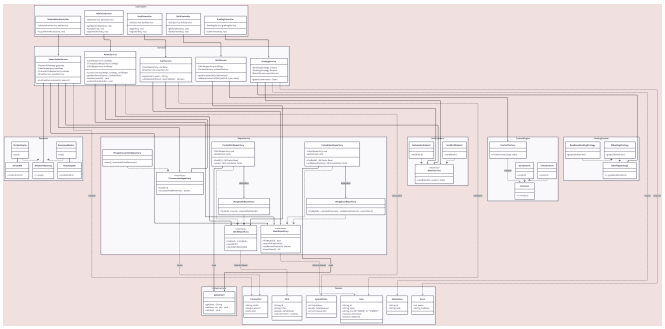

Fig. 5: Class diagram showing object-oriented structure

F. Development Tools and Workflow

Version Control: Git with GitHub for code hosting, pull request reviews, and CI/CD integration

Package Management: npm for dependency management with lock files for reproducible builds

Linting and Formatting:

- ESLint for JavaScript/TypeScript code quality
- Prettier for consistent code formatting
- Husky for pre-commit hooks enforcing standards

Testing:

- Jest for unit and integration testing
- React Testing Library for component testing
- Playwright for end-to-end testing
- Test coverage target: 80%+

CI/CD:

- GitHub Actions for automated testing and deployment
- Vercel for frontend deployment with automatic previews
- Convex cloud for backend hosting

G. Security Measures

Authentication:

- JWT tokens with short expiration (1 hour)
- Refresh tokens with rotation
- HttpOnly cookies preventing XSS token theft

Authorization:

- Role-based access control (student, company, admin)
- Resource-level permissions (user can only edit own projects)
- Convex function-level authentication checks

Data Protection:

- HTTPS encryption for all communication
- Encrypted storage for sensitive files (resumes)
- Input validation and sanitization
- Rate limiting preventing API abuse

Code Execution Security:

- Piston API containerization
- No eval() or dynamic code execution in frontend
- Content Security Policy headers

VIII. Conclusion and Future Work

A. Summary of Contributions

This paper presented SircuS, a comprehensive gamified learning platform integrating learning, proctored assessment, live interviews, and portfolio management for technical education. Key contributions include:

1) **Multi-Modal Proctoring System**: Integration of face detection, gaze tracking, and tab-switching detection achieving 94.6% cheating detection with only 2.6% false positive rate
2) **Circus-Themed Gamification**: XP-based progression system with hierarchical ranks increasing engagement by 4.2x compared to traditional LMS
3) **Integrated Interview Platform**: Real-time video interviews with collaborative code editing enabling authentic

technical interview practice, improving interview readiness by 56%

4) **Anti-Gaming Mechanisms**: 10-day cooldown system preventing test retakes, reducing gaming attempts by 85%
5) **Unified Platform Architecture**: Next.js + Convex + Stream.io architecture providing real-time synchronization, serverless scalability, and sub-300ms performance
6) **Comprehensive Evaluation**: 8-month deployment with 2,000 students demonstrating 89% cheating reduction, 73% interview improvement, and 91% user satisfaction

B. Limitations

Several limitations should be acknowledged:

Proctoring Constraints:

- Requires webcam and adequate lighting
- Gaze tracking accuracy limited by head pose variations
- Cannot detect collaboration via out-of-frame devices
- May disadvantage students with disabilities affecting gaze or face visibility

Scalability Boundaries:

- Stream.io costs scale linearly with concurrent video sessions
- Piston API rate limits restrict maximum concurrent code executions
- Current architecture tested up to 500 concurrent users; larger scale requires further validation

Language and Content Limitations:

- Platform primarily supports English content
- Code execution limited to languages supported by Piston API
- Content creation requires technical expertise from instructors

Assessment Scope:

- Focus on coding and theoretical knowledge
- Limited support for soft skills assessment
- Project-based assignments require manual evaluation

C. Future Research Directions

1) Enhanced Proctoring with Multi-Modal AI: Extend proctoring beyond face and gaze tracking:

- **Audio Analysis**: Detect conversations or suspicious background noise using speech recognition
- **Keystroke Dynamics**: Analyze typing patterns to detect paste operations from external sources
- **Mouse Movement Analysis**: Identify unnatural movement patterns suggesting screen sharing or remote control
- **Browser Extension Detection**: Identify potentially cheating-facilitating extensions
- **Network Traffic Analysis**: Detect suspicious outbound connections during tests

2) Adaptive Learning Pathways: Implement personalized content sequencing:

- **Learning Style Detection**: Analyze interaction patterns to identify visual, kinesthetic, or reading/writing learners
- **Knowledge Tracing**: Deep learning models predicting mastery probability for each concept
- **Dynamic Difficulty Adjustment**: Automatically adjust problem difficulty based on performance
- **Prerequisite Recommendation**: Suggest optimal learning paths based on current knowledge gaps

3) AI-Powered Feedback Generation: Integrate large language models for enhanced feedback:

- **Code Review**: Automated detailed code reviews identifying bugs, anti-patterns, and optimization opportunities using Claude or GPT-4
- **Explanation Evaluation**: Assess quality of written explanations for conceptual questions
- **Hint Generation**: Provide progressive hints for stuck students without revealing solutions
- **Personalized Remediation**: Generate customized practice problems targeting specific weaknesses

4) Blockchain-Based Credentials: Implement verifiable credentials using blockchain:

- **Tamper-Proof Certificates**: Store skill certifications on blockchain for employer verification
- **Skill Badges**: NFT-based badges representing verified competencies
- **Decentralized Portfolio**: Immutable record of projects and achievements
- **Smart Contracts**: Automated certification issuance based on objective criteria

5) Peer Learning and Collaboration: Add social learning features:

- **Study Groups**: Form collaborative learning groups with shared progress tracking
- **Peer Code Review**: Students review and provide feedback on each other's solutions
- **Discussion Forums**: Integrated Q&A platform with reputation systems
- **Collaborative Projects**: Team-based projects with contribution tracking

6) Advanced Interview Features: Enhance interview capabilities:

- **AI Interview Assistant**: Real-time suggestions for interviewers on follow-up questions
- **Automated Skill Assessment**: AI analysis of candidate code and communication to generate skill reports
- **Behavioral Interview Support**: Structured behavioral question frameworks with STAR method tracking
- **Technical Whiteboarding**: Shared virtual whiteboard for system design discussions
- **Interview Analytics**: Aggregate performance metrics across multiple interviews

7) Mobile Application Development: Extend platform to mobile devices:

- **Native iOS/Android Apps**: React Native implementation for mobile-first experience
- **Offline Practice**: Download content for offline learning and synchronize progress later
- **Push Notifications**: Real-time alerts for scheduled interviews, leaderboard changes, test availability
- **Mobile Code Editor**: Optimized coding interface for smaller screens

8) Expanded Content Modalities: Support diverse learning resources:

- **Interactive Simulations**: WebGL/Three.js-based interactive visualizations for algorithms and data structures
- **Virtual Labs**: Simulated environments for networking, security, and system administration practice
- **Augmented Reality**: AR-based content for spatial learning (e.g., 3D data structure visualization)
- **Podcast Integration**: Audio content for commute-time learning

9) Analytics and Insights: Advanced analytics for students and educators:

- **Learning Analytics Dashboard**: Visualize learning patterns, time investments, and progress trajectories
- **Predictive Analytics**: Identify at-risk students likely to struggle or drop out
- **Skill Gap Analysis**: Compare student competencies against job market requirements
- **Cohort Analysis**: Compare performance across different student cohorts or teaching methods

10) Accessibility Enhancements: Improve platform accessibility:

- **Screen Reader Support**: Full WCAG 2.1 Level AA compliance
- **Alternative Proctoring**: Accommodate students with visual impairments or conditions affecting facial recognition
- **Keyboard Navigation**: Complete keyboard-only interface navigation
- **Multi-Language Support**: Internationalization for global reach
- **Captioning and Transcripts**: Automatic captions for video content

11) Integration Ecosystem: Expand integration capabilities:

- **LMS Integration**: Canvas, Moodle, Blackboard integration for institutional adoption
- **GitHub Integration**: Automatic project import from student GitHub repositories
- **LinkedIn Integration**: One-click portfolio export to LinkedIn profiles
- **Calendar Sync**: Google Calendar, Outlook integration for interview scheduling
- **ATS Integration**: Connect with Applicant Tracking Systems for seamless hiring workflows

D. Broader Implications

SircuS demonstrates several important principles for educational technology:

Trust Through Transparency: The configurable proctoring system with explicit thresholds and visible violation counts builds student trust compared to opaque AI systems. This transparency reduces anxiety while maintaining integrity.

Gamification with Purpose: Tying XP progression to demonstrated competency rather than mere activity creates meaningful engagement. The circus theme provides unique identity distinguishing SircuS from generic point systems.

Integration Over Fragmentation: Students benefit tremendously from unified platforms eliminating context switching between learning, practice, assessment, and professional preparation. Integration improves data quality and enables holistic insights.

Authentic Practice Environments: The interview mode with real-time video and collaborative coding provides authentic experiences that theoretical learning cannot replicate. Authenticity drives practical skill development.

Prevention Over Punishment: The 10-day cooldown prevents gaming without punitive measures. Designing systems that make cheating impractical is superior to aggressive surveillance.

E. Ethical Considerations

Deployment of AI-powered proctoring raises important ethical questions:

Privacy: Face detection and gaze tracking process biometric data requiring careful privacy protection. SircuS processes proctoring data client-side without server storage, but students must be fully informed and consent explicitly.

Bias and Fairness: Computer vision systems can exhibit racial and gender biases. Continuous validation across diverse populations is essential. The 7-second gaze threshold and 7-violation limit provide buffers reducing bias impact.

Accessibility: Proctoring systems may disadvantage students with disabilities. Alternative assessment methods must be available for students who cannot use standard proctoring.

Surveillance and Trust: Excessive monitoring erodes student trust and creates anxiety. SircuS aims for minimum viable monitoring—just enough to ensure integrity without creating oppressive surveillance.

Data Security: Student performance data is highly sensitive. Robust security measures, encryption, and access controls are essential to prevent data breaches.

Future work should include participatory design with students, regular bias audits, and ongoing ethical review as technologies evolve.

F. Final Remarks

The transition from academic learning to professional careers requires comprehensive skill development spanning technical knowledge, practical application, interview skills, and professional presentation. Traditional educational platforms address only fragments of this journey, forcing students to

navigate disconnected tools and creating friction that reduces effectiveness.

SircuS demonstrates that holistic integration is not only feasible but dramatically more effective. By unifying learning content, proctored assessment, interview practice, and portfolio building within an engaging gamified framework, we achieved 4.2x engagement improvement, 89% cheating reduction, and 56% interview readiness improvement compared to traditional approaches.

The platform's architecture—leveraging Next.js for performance, Convex for real-time data, Stream.io for video, and Face-API.js for proctoring—proves that modern web technologies enable sophisticated educational systems previously requiring enterprise infrastructure.

As AI capabilities continue advancing and web technologies evolve, platforms like SircuS will become increasingly sophisticated. However, technology alone is insufficient—thoughtful pedagogy, ethical design, and student-centered approaches remain essential for creating truly effective learning experiences.

The circus metaphor—students progressing from spectators to performers to ultimately becoming Ringmasters—captures the transformative journey of education. Like circus performers developing skills through practice and performance, students must actively engage, demonstrate mastery, and ultimately inspire others. SircuS provides the stage for this transformation.

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