# Project Briefing: Smart Noise Detection System for University Library Table

**Project Type:** Human-Computer Interaction (HCI) Prototype  
**Context:** University Library — single small table installation (single user per table)  
**Hardware Platform:** ESP32 MCU Development Board  
**Primary Goal:** Promote and sustain a quiet library environment through responsive feedback and accountability, using adaptive sensing and machine learning–driven sound classification.

**1. Project Overview**

This project proposes a smart interactive table system designed for university library environments. The system detects user presence, authenticates users via ID cards, classifies and monitors sound levels using a lightweight AI model, and provides **real-time feedback** to promote desirable behaviors (quiet use of library space).

It incorporates **gamification elements** to positively reinforce user behavior and utilizes Firebase for backend communication and reporting through an API. The system will be embedded under an **acrylic frosted glass panel**, ensuring discreet operation and minimal visual distraction.

**2. Hardware Components**

* ESP32 MCU development board
* High-sensitivity microphone module
* IR obstacle avoidance sensor (single array)
* RC522 RFID reader + RFID cards
* Red and Yellow LED arrays
* 33 Ohm resistors
* Breadboard and wiring
* Small piezo buzzer (for audio feedback)

**3. System Interaction Flow**

**A. Idle State**

* No presence detected by IR sensor → LEDs OFF; system in power-saving mode.

**B. User Arrival & Authentication**

* IR sensor detects user → yellow LED flashes slowly.
* User prompted to scan university ID card (RFID).
* On successful scan:
  + User identity logged.
  + Yellow LED indicates active state (steady light or green if available).
  + Optional chime to confirm scan.

**C. Active Monitoring State**

* Adaptive background noise calibration starts (learns ambient noise).
* Lightweight **pre-trained AI sound classification model** (running on ESP32 or streamed via Firebase):
  + Classifies common sounds:
    - Typing / page flipping (allowed)
    - Whispering (allowed)
    - Talking (monitored)
    - Loud talking or laughing (offense)
    - Object drops / non-verbal sharp noises (ignored)
* **On offense (e.g. loud talking or laughing)**:
  + Red LED array flashes rapidly (~5 sec).
  + Short chime/beep for feedback.
  + Offense is counted.

**D. Offense Escalation & Reporting**

* If **3 offenses within 5 minutes**:
  + API call sent to backend via Firebase:
    - Table ID
    - User ID
    - Time
    - Offense count
  + Admin notified via external API integration (SMS, email, or notification system).

**E. User Exit Detection**

* If **no sound and no movement** detected for e.g. 3 minutes:
  + Decaying timer resets the system.
  + Returns to idle state, ready for new user.

**4. Gamification Features**

* Each table maintains a **“quietness score”** (stored in Firebase):
  + High scores for tables with low offenses.
  + Users contributing to a "quiet table" see **positive feedback**:
    - Green LEDs after extended quiet period.
    - Optionally displayed in library app/website as “Quiet table of the day/week.”
* Encourages positive behavior by rewarding rather than only penalizing.

**5. HCI & Design Principles**

* **Real-time and multimodal feedback** (visual + sound).
* **Accountability and transparency** through offense tracking.
* **Adaptive calibration** for dynamic environments.
* **Positive reinforcement** through gamification.
* **Privacy-conscious**: stores minimal user data.
* **Modular design** — intended for per-table installation (single user unit per table).

**6. Future Work / Extensions**

* Improved AI model using TensorFlow Lite Micro (TFLM) optimized for ESP32.
* Crowd-sourced data labeling to improve sound classification model.
* Expanded gamification metrics.
* Mobile app integration to show personal offense record and user rankings (opt-in).
* Further tuning for false-positive and false-negative handling.

**Conclusion:**  
This project represents a sophisticated HCI prototype for **behavior shaping in shared academic environments**. It integrates **real-time sensing**, **lightweight AI**, **adaptive feedback**, and **positive reinforcement**, while maintaining modularity and scalability through modern cloud-based architecture (Firebase + API).