C-MAP Braille, a Confusion Mapping Adaptive System for Accelerated Braille Literacy

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Braille literacy rates collapsed from over 50% four decades ago to under 10% today (National Federation of the Blind, 2020), driven by instructor shortages and fixed curricula unable to adapt to individual error profiles. Prior ISEF entries — BrailleSense (2025) and eiBraille (2024) — addressed hardware accessibility but not learner-specific confusion. No prior Braille system conducted a randomised controlled trial comparing adaptive versus fixed-curriculum instruction. This study developed C-MAP Braille, a confusion-mapping adaptive platform using a six-dot refreshable tactile display, dual-processor architecture (Arduino Uno; Raspberry Pi 4), and tactile sensors. The Weighted Adaptive Reinforcement Algorithm (WARA) maintained a live 26×26 confusion matrix and weighted drill selection inversely to accuracy, with floor probability epsilon = 0.05 ensuring no character was permanently excluded. Twenty-four visually impaired participants (ages 13–17) were assigned to adaptive (n=12) or fixed-curriculum (n=12) groups across 11 sessions, with dot height counterbalanced across 0.5 mm and 0.8 mm conditions. The adaptive group reached 90% proficiency in 6.2 sessions; no control participant reached this threshold (t(22) = 4.31, p = 0.003, d = 1.76). Confusion-pair errors decreased 77.2% versus 36.9% (p = 0.001). NASA-TLX scores diverged by Session 10 (37.2 vs 57.1, partial eta^2 = 0.38). Elevated dot height improved accuracy by 10.9 percentage points in below-median tactile sensitivity participants only (p = 0.007). Real-time confusion-mapping drove significantly faster Braille acquisition — a finding no prior ISEF Braille project has produced — with implications for scalable literacy interventions globally.

Awards Won:
Sigma Xi, The Scientific Research Honor Society: First Award Behavioral and Social Science Award of $1,200