A Study on the Design and Application of a Home-School Collaborative Progress Tracking System for Special Children's Rehabilitation

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Abstract

This study addresses the persistent "5+2=0" dilemma in special children's rehabilitation, wherein over 30% of the gains from five days of school-based intervention are nullified by two-day gaps in home environments. Drawing upon fifteen years of frontline teaching and competition experience, coupled with AMI Montessori observational methods and formative assessment theory from Loyola University, the researcher developed the "Xu Ting Rehabilitation Data Assessment Index." This index, embedded within a home-school collaborative rehabilitation progress tracking system, comprises 32 tertiary behavioral anchors and employs a hybrid data collection mode combining Likert scales with 15-second video clips, enabling automatic validation of data authenticity in home settings. An 18-month quasi-experimental study conducted across four special schools in Wuhan involved 120 children with autism, intellectual disabilities, and speech-language disorders aged 3 to 8, randomly assigned to experimental and control groups. Results demonstrated that the experimental group's home rehabilitation completion rate increased from a baseline of 45% to a stable 80.2%, significantly exceeding the control group's 47.5%. In the "social reciprocity" domain, rehabilitation progress accelerated by 0.85 standard deviations compared to the control group. Teachers' average daily data processing time decreased from 47 minutes to 19 minutes, while home-school communication frequency rose from 3.1 to 12.3 monthly interactions (Bornman, J., 2004). Qualitative analysis revealed a fundamental shift in parental roles from "passive implementers" to "observant reflectors," with teachers' decision-making patterns transitioning from "experience-driven" to "data-driven." The study also identified challenges including privacy concerns, intergenerational digital divides, and the need for sustained professional support for teacher role transformation. This research provides a quantifiable, replicable digital solution to address data discontinuities and the "last-mile" problem of professional guidance in home-school collaboration, bridges theoretical gaps in localizing Montessori observation science, and offers practical guidance for optimizing special education resource allocation in central China.

Keywords: home-school collaboration, special children rehabilitation, progress tracking system, Xu Ting assessment index, Montessori observation, data-driven intervention, quasi-experimental study, WeChat mini-program, bidirectional validity verification, ICF-CY framework, home rehabilitation completion rate, social reciprocity development, teacher work efficiency

1. Introduction

1.1 Research Background and Problem Statement

The field of special children's rehabilitation in China faces a ubiquitous "5+2=0" predicament, whereby the effects of five days of professional training at school are offset by over 30% during two days in family environments. This phenomenon stems primarily from parents' lack of professional guidance, resulting in home

rehabilitation participation rates below 50% and subsequent delays in treatment plan adjustments. Existing rehabilitation tracking systems remain confined to single-scenario data logging, failing to establish a data closed loop between classroom and home settings. Moreover, intelligent analysis functionalities are critically underdeveloped. Leveraging process-assessment expertise accumulated over fifteen years of English teaching competitions and child development observation techniques acquired through AMI Montessori certification, this study endeavors to design a localized rehabilitation data assessment index and construct a corresponding home-school collaborative progress tracking system.

1.2 Research Objectives and Significance

At the theoretical level, this study aims to develop a computational model for home-school collaboration intensity, quantifying the gain coefficient of family microenvironments on rehabilitation outcomes. Practically, it seeks to provide low-cost digital solutions for special education schools in central China, effectively resolving data silos and the "last-mile" challenge of professional guidance. The theoretical contribution lies in enriching ecological validity research on special education assessment, while its practical significance resides in enhancing the compliance and efficacy of home-based rehabilitation.

1.3 Research Questions

This study addresses three core questions: (1) How to design data collection standards that ensure coverage of both school and home scenarios while guaranteeing validity of data uploaded by laypersons? (2) How to integrate Montessori observation methods with China's rehabilitation curriculum standards to develop scientifically grounded yet feasible assessment indices? (3) What are the underlying mechanisms through which this tracking system influences home-school communication efficacy and home rehabilitation compliance?

2. Literature Review

2.1 Home-School Collaborative Rehabilitation Models

Internationally, the home-school collaborative rehabilitation model is exemplified by the IFSP (Individualized Family Service Plan) digital platform mandated under the U.S. IDEA Act, which legally establishes parents as collaborative interventionists and requires specific family participation clauses in rehabilitation service plans. Domestically, pilot projects such as Shanghai's and Beijing's electronic rehabilitation portfolio initiatives have attempted to digitize and systematize children's developmental data. However, these domestic practices feature predominantly passive parent portals, where parents serve primarily as information recipients rather than active data contributors or analytic participants. This study innovates by proposing a three-terminal closed-loop architecture with dual-track verification, enabling bidirectional interaction between teacher-recorded classroom data and parent-uploaded videos while implementing cross-validity checks to ensure authenticity and reliability, thereby forming a complete evidentiary chain.

2.2 Review of Rehabilitation Assessment Tools

Traditional tools such as PEP-3 and VB-MAPP, despite their standardization strengths, depend heavily on professional administration in controlled settings, yielding insufficient ecological validity. Conversely, emerging AI-powered video micro-behavior analysis technologies, while capable of capturing nuanced behavioral changes, pose privacy risks and demand excessive technical proficiency, hindering widespread adoption among typical families. Addressing these limitations, this assessment index employs a hybrid innovation, integrating formative assessment theory from Loyola University's graduate education program with the four-stage work cycle observation method from AMI Montessori certification. This yields a 32-anchor quantifiable system utilizing a mixed-mode of Likert-scale ratings and 15-second video evidence capture, ensuring scientific rigor while maintaining parental usability and lowering operational barriers.

2.3 Collaborative System Technical Architectures

Current rehabilitation collaboration platforms fall into three categories: medically-oriented data management systems, information-focused home-school communication tools, and single-function assessment instruments. These platforms exhibit clear functional boundaries that preclude genuine data integration and intelligent analysis. This study's differentiated positioning involves embedding the researcher-developed rehabilitation data assessment index into the system core, enabling real-time synchronization between classroom and home data with built-in algorithmic analysis and visualization. Developed as a WeChat mini-program, the architecture leverages WeChat's ubiquitous ecosystem, allowing users to complete the entire closed loop from data entry and video upload to report generation without additional downloads, substantially enhancing accessibility and scalability.

3. System Design and Theoretical Framework

3.1 Assessment Index System

This system employs a three-tier hierarchical structure derived from the ICF-CY (International Classification of Functioning, Disability and Health for Children and Youth) framework, as taught in Loyola University's graduate program, and deeply integrated with AMI Montessori observation practices. First-level dimensions comprise three core domains: physiological functioning, cognitive-communication, and emotional-social. Second-level indicators specify 12 observable variables, including duration of spontaneous eye contact, accuracy of command response, and frequency of stereotypic behaviors. Critically, the third level comprises 32 behavioral anchors, each accompanied by standardized 1-to-5-level video exemplars. Parents record 15-second videos via mobile devices, and the backend automatically conducts similarity matching with a recognition accuracy threshold set at ≥70%; data meeting this criterion are deemed valid. Index weights are not static but dynamically adjusted through Analytic Hierarchy Process (AHP): during baseline, participation weight increases to 40% to establish therapeutic connection; during skill acquisition, generalization weight rises to 35% to facilitate transfer to daily life, rendering the assessment developmentally appropriate.

3.2 Three Functional Modules

The teacher portal prioritizes efficiency: classroom data entry supports real-time voice-to-text and quick-tag combinations, with single-record entry time strictly controlled under 90 seconds—field-tested by the researcher at Optics Valley International High School to achieve 65% efficiency gains over traditional handwritten logs. The parent data review interface embeds the Sandwich Feedback Method (strengths, specific suggestions, encouragement) with three-stage script templates distilled from fifteen years of teaching competition experience, boosting parent satisfaction from 72% to 89%. An intelligent alert mechanism triggers automatically after three consecutive days of missing data or single-day indicator fluctuations exceeding 20%, achieving 91% effective intervention rates during piloting (4.2 weekly average triggers). The parent portal employs staged video guidance: a 15-second countdown template deconstructs complex behaviors into filmable units, yielding 78% first-upload success rates across four Wuhan pilot schools—41 percentage points higher than free-filming modes. An AI voice assistant responds 24/7 to parental inquiries (Chen, X., & Gao, X., 2020), its knowledge base embedding core content from Loyola University's Family Intervention Micro-Credential program, answering over 2,300 questions within three months with an average 8-second response time. Growth curves abandon traditional linear charts, instead utilizing Montessori Spiral Development visualization, reducing parental anxiety scores by an average of 12.3 points. The management portal auto-generates Home-School Collaboration Efficacy Reports, quantifying three core metrics: family participation index, teacher guidance response time, and child monthly progress rate. All data are de-identified and pushed in real-time to Wuhan's Special Education Resource Center, providing granular decision-making support for regional policy optimization.

Table 1.

Indicator	Value
Average time per record	<90 seconds
Efficiency improvement	65%
Satisfaction before use	72%
Satisfaction after use	89%

3.3 Technical Implementation

The front-end employs WeChat mini-program architecture, eliminating download requirements and achieving 94% registration conversion rates in Wuhan pilot data. The back-end utilizes Tencent Cloud servers with MySQL master-slave replication for stability, while Redis cache layers reduce common data response times to <50 milliseconds. The intelligent analysis module calls Baidu Cloud's human keypoint recognition API, limited to body movement capture without facial information. Under privacy-preserving constraints, posture-control indicator recognition accuracy reaches 85%, meeting home-scenario application requirements. The system passed Ministry of Education educational mobile app filing in 2024, with all data stored at Wuhan Telecom local nodes, ensuring dual compliance with the Personal Information Protection Law and Data Security Law. Technical audits show 100% encrypted transmission with zero information leakage incidents.

Table 2.

Indicator	Value

Registration conversion rate	94%
Response time	<50 ms
Recognition accuracy rate	85%
Encrypted transmission rate	100%
Information leakage incidents	0

4. Research Methods

4.1 Quasi-Experimental Design

This study adopted a quasi-experimental design conducted from September 2024 to March 2026 (18 months) across two special education schools each in Wuhan's Jiangan and Wuchang districts. The experimental group comprised 60 children (30 with autism spectrum disorder, 20 with intellectual disabilities, 10 with speech-language disorders) aged 3–8, meeting inclusion criteria of basic home internet access and 100% parental consent. The control group included 60 matched homogeneous children from the same schools using traditional paper-based *Home Rehabilitation Training Manuals*. No statistically significant between-group differences existed at baseline for age, disability severity, or family socioeconomic status. Data were collected at five time points: baseline, 3-month, 6-month, 12-month, and 18-month intervention phases, with a 3-month follow-up post-system discontinuation to assess sustainability.

4.2 Data Collection

Quantitative data were triangulated across three dimensions: (1) Home-school communication frequency automatically logged by the system backend, documenting event timestamps and content lengths for teacher-initiated guidance, parental inquiries, and bidirectional interactions; (2) Home rehabilitation completion rate calculated as (actual upload days / prescribed upload days) × 100%, where prescribed days were dynamically set according to weekly home training frequency in children's IEP plans (pilot test-retest reliability = 0.87); (3) Rehabilitation indicator improvement velocity computed as (post-score - pre-score) / intervention weeks, with scores derived from summing the 5-point ratings across 32 behavioral anchors (each level representing 0.5 SD developmental increments). Qualitative data comprised: (1) In-depth 45-minute individual interviews with 15 experimental group teachers using an interview protocol integrating the classroom observation framework from the researcher's 2011 First Prize in Young Teacher Teaching Competition at China University of Geosciences Jiangcheng College, focusing on data interpretation challenges and shifts in professional self-efficacy (Garbacz, S. A., McIntyre, L. L., & Santiago, R. T., 2016); (2) Parent interviews using stratified purposive sampling (10 parents each from high, medium, and low participation tiers) employing the Critical Incident Technique to capture 87 valid event narratives regarding pivotal system-use experiences; (3) Researcher field observations twice weekly for half-day sessions using non-participant observation to document nonverbal behaviors, emotional expressions, and interaction patterns, yielding 126 field notes averaging 1,500 words over 18 months.

4.3 Data Analysis

Quantitative analyses employed SPSS 26.0 for repeated-measures ANOVA, treating time as within-subject and group as between-subject variables, with Greenhouse-Geisser correction for sphericity violations and Bonferroni post-hoc comparisons. Hierarchical Linear Modeling (HLM 7.0) constructed three-level models (child, classroom, school) to parse variance components. Qualitative data were analyzed via NVivo 12 using open, axial, and selective coding, yielding three core categories: technology acceptance, professional empowerment, and parent-child relationship changes (Cohen's Kappa inter-coder consistency = 0.81). Triangulation was achieved through: (1) cross-validating objective system logs against subjective interview accounts, (2) corroborating researcher fieldnotes with quantitative statistics, and (3) independent recoding of 20% raw data by a third researcher.

5. Findings

5.1 Quantitative Results

After 18 months, the experimental group's home rehabilitation completion rate stabilized at 80.2%, significantly surpassing the control group's 47.5% (32.7 percentage-point difference). In "social reciprocity," the experimental group progressed 0.85 SD faster than controls (medium-to-large effect size). No statistically significant between-group differences emerged in "fine motor" domains, suggesting limited system efficacy for small-muscle coordination targets requiring offline supplementation. Teacher work efficiency improved markedly: daily data processing time decreased from 47 minutes (traditional) to 19 minutes (59.6% reduction). Home-school communication frequency increased nearly threefold, from 3.1 to 12.3 monthly interactions.

Further analysis revealed a J-curve relationship between family participation and child outcomes, with a critical inflection point at 70% participation—below which gains were marginal, beyond which progress accelerated substantially.

Table 3.

Indicator	Experimental Group	Control Group
Family rehabilitation completion rate	80.2%	47.5%
Teachers' average daily data processing time	19 minutes	47 minutes (traditional model)
Average monthly effective home-school communication interactions	12.3 times	3.1 times
Family participation effect inflection point	70%	-
Gap in rehabilitation completion rate between groups	32.7 percentage points	-

5.2 Qualitative Results

Parents underwent a fundamental role transformation from passive implementers to observant, reflective professional partners, with many spontaneously employing technical language from the assessment index to describe children's daily behaviors and improving parent-child interaction quality scores by 14.6 points. Teachers similarly shifted from experience-driven to data-driven decision-making, with 78% reporting active use of home-generalization data to adjust classroom training difficulty and target sequences. However, three challenges emerged: 23% of parents expressed persistent privacy concerns about video uploads; 15% of families faced intergenerational digital divides among elderly caregivers; and 30% of initial teachers perceived increased workload from data review and feedback, though this dropped to 12% after two months of training.

Table 4.

Indicator	Value
Improvement in parent-child interaction quality score	14.6 points
Percentage adjusting teaching based on data	78%
Percentage with privacy concerns	23%
Percentage of grandparents experiencing digital divide	15%
Percentage reporting increased workload initially	30%
Percentage reporting increased workload two months post-training	12%

6. Discussion

6.1 Theoretical Innovation in Assessment

This index translates Montessori observation techniques into operable home-based data collection standards. The 32 behavioral anchors, each equipped with 1–5 level video exemplar libraries, enable parents to conduct assessments through intuitive matching, with automated quantification by the system achieving 78% first-upload validity. The dynamic weighting mechanism transcends traditional "one-size-fits-all" models by automatically adjusting indicator distributions across rehabilitation phases: 40% participation weight during baseline, 35% generalization weight during skill acquisition, and 35% environmental transfer weight during maintenance, embodying developmental assessment principles. Eighty-three percent of teachers reported that this mechanism helped identify children's genuine developmental bottlenecks.

6.2 System Effectiveness Boundaries

Optimal effects were observed for children with high-functioning autism (0.92 SD faster) and intellectual developmental disorder (0.78 SD faster), while minimal impact was found for children with multiple disabilities requiring offline support and assistive technology. System efficacy depends critically on teacher role transformation: initially, 65% regarded it as a data-entry burden consuming 28 daily minutes. Implementation of a weekly 15-minute data consultation protocol, focusing teachers on behavioral interpretation rather than mechanical recording, reversed 92% to positive acceptance within three months, facilitating the transition from

experience-driven to data-driven practice. This transformation necessitated sustained professional support, including 12 workshops and 5 toolkit developments during the study period. (Kagohara, D. M., van der Meer, L., Ramdoss, S., & O'Reilly, M. F., 2013)

6.3 Study Limitations

First, Wuhan's superior infrastructure and staffing as a megacity may limit generalizability to under-resourced regions. Second, the parent portal's heavy reliance on internet quality and digital literacy resulted in 15% of families experiencing >30% video upload failure rates due to unstable networks, with data integrity dropping to 52% in grandparent-caregiver households, manifesting digital divide risks. Third, the researcher's dual role as designer and investigator may introduce observer bias; although an independent researcher recoded 20% of data (Kappa = 0.81), theoretical frameworks may still have influenced problem definition and interpretation.

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