

# NeuroRoad: An AI-Assisted Role-Based Learning Management System for Neurodivergent Education

Alen Siju Mudakodil

Computer Science and Engineering  
St. Joseph's College of Engineering and Technology  
Palai, India  
alensijumudakodil2026@cs.sjcetpalai.ac.in

Alwin J Thomas

Computer Science and Engineering  
St. Joseph's College of Engineering and Technology  
Palai, India  
alwinjthomas2026@cs.sjcetpalai.ac.in

Awindas R

Computer Science and Engineering  
St. Joseph's College of Engineering and  
Technology  
Palai, India  
awindasr2026@cs.sjcetpalai.ac.in

Chris Reji Kuriakose

Computer Science and Engineering  
St. Joseph's College of Engineering and Technology  
Palai, India  
chrisrejikuriakose2026@cs.sjcetpalai.ac.in

Prof. Sarju S

Computer Science and Engineering  
St. Joseph's College of Engineering and Technology  
Palai, India  
sarju.s@sjcetpalai.ac.in

**Abstract**—Neurodivergent learners, which includes individuals with Autism Spectrum Disorder (ASD), Attention-Deficit/Hyperactivity Disorder (ADHD) and Dyslexia, require personalized instructions that go beyond the capabilities of existing learning management systems (LMS). Most already existing platforms give more importance to personalized content delivery and assessment, offering limited support for behavioral monitoring, clinical collaboration, and long-term intervention evaluation. This paper presents NeuroRoad, an AI assisted, role-based learning management system developed to facilitate personalized education and coordinated therapeutic workflows for neurodivergent students.

The platform supports structured collaboration among students, parents, psychologists, and administrators through clearly defined roles and access controls. NeuroRoad integrates condition-specific assessments, adaptive learning exercises, structured behavioral observations, intervention planning, and consultation scheduling within a unified environment. AI assisted analytics are employed to identify learning trends and behavioral patterns, providing interpretable insights while ensuring that all educational and clinical decisions remain under professional human supervision. The system is implemented using a scalable monorepo architecture with a modern web frontend, a modular backend, and a relational database for longitudinal data management. NeuroRoad demonstrates how ethically guided AI integration and collaborative system design can enhance personalized learning and intervention effectiveness in neurodivergent education.

**Index Terms**—Neurodivergent Education, Learning Management Systems, Adaptive Learning, Artificial Intelligence in Education, Behavioral Analytics, Clinical Decision Support

## I. INTRODUCTION

Educational environments across the world have traditionally relied on standardized teaching methodologies that as-

sume learners progress at similar cognitive rates and respond uniformly to instructional practices. While this approach may simplify curriculum planning and assessment, it often fails to address the diverse cognitive profiles of students who do not conform to neurotypical developmental patterns. Neurodivergent learners including individuals diagnosed with Attention-Deficit/Hyperactivity Disorder (ADHD), Autism Spectrum Disorder (ASD), Dyslexia, Dyspraxia, and other neurodevelopmental conditions—frequently experience challenges that require specialized instructional support.

Neurodivergent students may demonstrate differences in attention span, sensory processing, working memory, executive functioning, emotional regulation, and communication. These characteristics influence not only academic performance but also engagement, motivation, and classroom behavior. Therefore, traditional learning systems that emphasize uniform assessments and fixed instructional pacing often overlook the needs of such learners.

In neurodivergent education, learning outcomes depend heavily on consistent environmental support, structured feedback, personalized learning pathways, and collaboration between educators and clinical professionals. Short-term standardized examinations may not accurately reflect progress, as neurodivergent learners often show fluctuating performance due to emotional, sensory, or behavioral factors. Continuous formative assessment and contextual observation become essential for meaningful evaluation.

Furthermore, supporting neurodivergent learners requires collaboration among multiple stakeholders, including parents, teachers, psychologists, therapists, and administrators. How-

ever, current educational workflows remain fragmented, relying on disconnected tools and informal reporting mechanisms. This fragmentation delays interventions and reduces accountability.

Recent developments in artificial intelligence have introduced adaptive learning technologies capable of customizing educational content based on student performance. Despite this promise, many AI driven platforms prioritize automation without adequate transparency, raising ethical concerns regarding bias, explainability, data privacy, and professional responsibility.

To address these limitations, this paper introduces NeuroRoad, an AI assisted role based learning management system designed specifically to support neurodivergent learners through personalized education, behavioral monitoring, and coordinated therapeutic workflows.

## II. RELATED WORK

Adaptive learning systems and intelligent tutoring platforms have gained significant attention due to their ability to enhance engagement and academic achievement. These systems typically analyze learner performance data, response accuracy, and interaction patterns to dynamically adjust instructional difficulty and sequencing. Studies have demonstrated that adaptive learning can improve motivation and reduce dropout rates in general education settings.

However, most adaptive platforms are designed primarily for neurotypical learners and do not fully incorporate the cognitive variability and behavioral diversity associated with neurodivergent populations. Neurodivergent learners often require multimodal instruction, reduced cognitive load interfaces, and emotionally supportive feedback mechanisms, which are absent in many conventional systems.

Learning analytics and educational data mining research has also explored predicting academic outcomes, detecting disengagement, and identifying learning difficulties. Behavioral monitoring tools have been proposed to track participation levels, emotional states, and attention indicators. While promising, these solutions are often limited to isolated analytics components without integrating clinical expertise or parental observations.

Conventional LMS platforms such as Moodle, Blackboard, and Google Classroom provide role based access control for teachers, students, and administrators. However, they lack specialized workflows tailored for neurodivergent education, such as structured behavioral reporting, longitudinal intervention tracking, and therapist educator collaboration.

Ethical AI considerations including transparency, interpretability, and human in the loop oversight—remain insufficiently addressed in most educational AI systems. NeuroRoad distinguishes itself by integrating adaptive learning with clinical collaboration while ensuring AI serves as a supportive tool rather than an automated decision-maker.

## III. PROPOSED SYSTEM

NeuroRoad is proposed as a collaborative role based learning management system specifically developed to address the

TABLE I  
COMPARISON WITH CONVENTIONAL LMS PLATFORMS

Feature	Moodle	Google Classroom	NeuroRoad
Adaptive Learning Support	Limited	No	Yes
Behavioral Monitoring	No	No	Yes
Therapist Collaboration	No	No	Yes
AI-Assisted Analytics	Limited	No	Yes
Intervention Tracking	No	No	Yes

educational and therapeutic needs of neurodivergent learners. The platform integrates adaptive learning modules, behavioral monitoring tools, and AI assisted analytics within a unified environment.

The system defines four primary user roles:

-Administrator: Responsible for platform configuration, user management, content moderation, and policy enforcement.

-Psychologist/Therapist: Manages student caseloads, assigns assessments, evaluates longitudinal data, and develops intervention plans.

Parent/Caregiver: Provides structured behavioral observations, monitors progress, and participates in consultation workflows.

Student: Engages with adaptive learning content, completes tasks, and tracks personal progress indicators.

A centralized longitudinal data model stores academic metrics, behavioral reports, intervention records, and engagement trends over time. This integrated data enables evidence based decision-making and continuous refinement of learning strategies.

Role-based access control ensures privacy and accountability by restricting sensitive clinical information to authorized professionals while maintaining collaborative transparency among stakeholders.

## IV. METHODOLOGY

The methodology adopted for the development of NeuroRoad focuses on integrating adaptive learning technologies, structured behavioral monitoring, and AI assisted clinical decision support within a secure and ethically guided learning management framework. Since neurodivergent learners require individualized instructional strategies, the platform is designed to accommodate cognitive diversity while ensuring transparency, usability, privacy, and scalability.

NeuroRoad's methodological foundation is built upon five core components: role based system design, adaptive learning assessment, behavioral observation tracking, AI assisted analytics, and modular system integration. Each component contributes to creating an inclusive and collaborative environment for educational and therapeutic stakeholders.

### A. Role Based System Design

NeuroRoad employs a structured Role Based Access Control (RBAC) model to enforce security, accountability, and workflow clarity across all system users. Neurodivergent education requires collaboration among multiple stakeholders such as psychologists, educators, parents, and administrators.

Therefore, it is essential that each participant accesses only the information relevant to their responsibilities.

The system defines four primary roles:

**Administrator:** Manages system configuration, user authentication, access permissions, and institutional policy enforcement.

**Psychologist/Therapist:** Conducts cognitive assessments, monitors intervention outcomes, and designs personalized support plans.

**Parent/Caregiver:** Submits behavioral observations from home environments and participates in consultation workflows.

**Student:** Engages with adaptive learning content, completes assessments, and tracks progress indicators.

Role-specific dashboards are developed with simplified layouts to minimize cognitive load, especially for neurodivergent learners and caregivers. This ensures usability and prevents overwhelming interfaces that may reduce engagement.

Additionally, the RBAC framework ensures compliance with ethical guidelines by restricting sensitive clinical data access to authorized professionals while promoting collaborative transparency.

### B. Adaptive Assessment and Learning Framework

A key methodological contribution of NeuroRoad is its adaptive assessment and personalized learning engine, designed specifically for neurodivergent cognitive variability. Traditional LMS assessments are often static and standardized, which may not accurately reflect neurodivergent learner progress due to fluctuating attention, sensory sensitivities, or emotional regulation challenges.

NeuroRoad implements condition sensitive assessments targeting domains such as:

- Attention and focus consistency
- Executive functioning skills
- Language comprehension and reading ability
- Behavioral response patterns
- Memory retention and mastery development

The learning framework integrates multimedia-based instructional resources, including:

- Visual aids and structured diagrams
- Interactive exercises and gamified tasks
- Step by step scaffolding mechanisms
- Reinforcement based feedback

Learning pathways are dynamically adjusted using learner performance history, engagement trends, and mastery indicators. NeuroRoad adopts a hybrid adaptation methodology combining:

-Pedagogical Rule Based Adaptation: Ensuring instructional coherence and structured progression.

-Data Informed Personalization: Leveraging AI supported insights to tailor pacing and difficulty.

-This hybrid approach ensures personalization without compromising educational consistency.

### C. Behavioral Observation and Intervention Tracking

Academic assessments alone cannot fully capture neurodivergent learner development, as behavioral and emotional factors strongly influence learning outcomes. Therefore, NeuroRoad integrates structured behavioral monitoring as a core methodological element.

Parents and caregivers submit behavioral observations using standardized reporting templates with severity scales. Observations may include:

- Attention fluctuations
- Emotional dysregulation episodes
- Sensory overload responses
- Social interaction patterns
- Task completion behaviors

This data provides real world context beyond classroom performance and supports psychologists in developing evidence-based interventions.

Behavioral records are linked directly with intervention plans, allowing professionals to track:

- Intervention effectiveness over time
- Improvement consistency
- Behavioral pattern changes
- Support strategy refinement

This longitudinal intervention methodology strengthens clinical accountability and continuous improvement in learner support. The behavioral monitoring process is illustrated in Fig. 1.

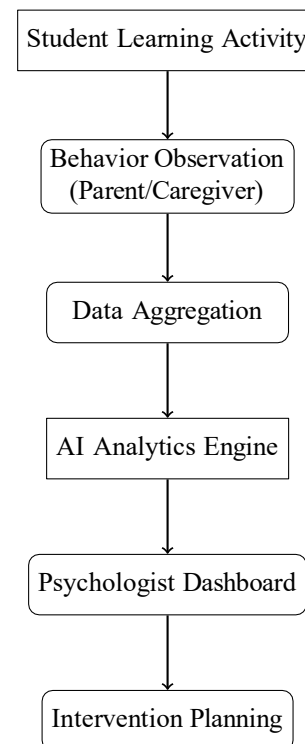


Fig. 1. Behavioral Monitoring and Intervention Workflow

#### D. AI-Assisted Analytics and Decision Support

NeuroRoad incorporates AI assisted analytics to enhance learning insights while maintaining ethical safeguards. Unlike fully automated AI tutoring systems, NeuroRoad follows a human in the loop methodology, where AI provides supportive recommendations but final decisions remain under professional control.

AI modules process aggregated academic and behavioral data to identify:

- Learning progression trends
- Engagement inconsistencies
- Behavioral anomalies
- Intervention response outcomes

Insights are presented through interpretable dashboards, including:

- Mastery growth indicators
- Weekly engagement summaries
- Behavioral severity trend charts
- Personalized support suggestions
- By focusing on explainability rather than automation, NeuroRoad ensures transparency, reduces bias risks, and builds trust among educators, caregivers, and clinicians.

#### E. AI Model Implementation

The AI analytics component of NeuroRoad is designed to analyze longitudinal academic and behavioral data in order to identify learning patterns, engagement fluctuations, and potential intervention requirements. The system employs a hybrid machine learning pipeline consisting of data preprocessing, feature extraction, behavioral pattern analysis, and predictive modeling.

Student interaction logs, assessment scores, behavioral observations submitted by caregivers, and engagement indicators such as task completion rate and response time are continuously collected. These datasets are processed through a pre-processing stage that removes inconsistencies and normalizes behavioral severity scores.

Feature extraction is performed to identify relevant learning indicators including:

- task completion time
- response accuracy
- attention consistency
- behavioral severity trends
- engagement frequency

These features are used as inputs to supervised learning models that classify learners based on support requirements and engagement levels. Random Forest and Gradient Boosting models are employed due to their interpretability and robustness in educational analytics tasks.

The predictive model categorizes learners into support categories such as:

- stable learning progression
- moderate engagement fluctuation
- high intervention requirement

The model outputs are visualized through role specific dashboards that allow psychologists and educators to identify

learning difficulties early and adjust instructional strategies accordingly. Importantly, NeuroRoad adopts a human in the loop framework, ensuring that AI insights support professional decision-making rather than replacing it.

TABLE II  
FEATURES USED FOR AI-BASED LEARNING ANALYTICS

Feature	Description
Task Completion Time	Time taken by student to complete learning tasks
Response Accuracy	Percentage of correct responses in assessments
Engagement Frequency	Number of interactions with learning modules
Behavioral Severity Score	Caregiver-reported behavioral observation rating
Attention Consistency	Stability of learner attention during sessions

#### F. System Integration and Data Architecture

The system architecture of NeuroRoad follows a modular and scalable design methodology to ensure maintainability and future extensibility. The platform integrates frontend learning interfaces, backend analytics services, and centralized databases through a unified data layer.

Key architectural principles include:

-Modularity: Each system component (assessment, behavioral tracking, analytics) functions independently while remaining interoperable.

-Scalability: Supports expansion to larger student populations and institutional deployments.

-Security: Secure authentication and authorization mechanisms protect sensitive learner data.

-Longitudinal Data Modeling: Academic and behavioral metrics are stored in relational structures to enable time-based analysis and intervention tracking.

Real time synchronization ensures that psychologists, parents, and educators receive updated progress information without delays.

This integration methodology ensures NeuroRoad remains reliable, extensible, and ethically aligned with neurodivergent education requirements.

## V. SYSTEM ARCHITECTURE

The NeuroRoad platform follows a modular three tier architecture consisting of a presentation layer, application layer, and data layer. This architecture ensures scalability, maintainability, and secure data management for educational and clinical workflows. As shown in Fig. 2, NeuroRoad follows a modular architecture that integrates adaptive learning modules, behavioral monitoring components, and AI-assisted analytics.

#### A. Presentation Layer

The presentation layer consists of web-based user interfaces designed for different stakeholders including students, caregivers, psychologists, and administrators. Each role is provided with a customized dashboard that displays relevant analytics, learning modules, and behavioral monitoring tools.

B. Application Layer

The application layer contains the core system services responsible for platform functionality. These include:

- adaptive learning engine
- behavioral monitoring module
- AI analytics engine
- intervention planning module
- user authentication and access control system

These services communicate through RESTful APIs to ensure modular integration and flexible system expansion.

C. Data Layer

The data layer stores academic performance metrics, behavioral observation reports, intervention records, and engagement logs. A relational database structure is used to maintain longitudinal student data, enabling time-based analytics and evidence-driven intervention planning.

Secure authentication protocols and role based access control ensure that sensitive clinical data is accessible only to authorized professionals while still enabling collaborative transparency among stakeholders.

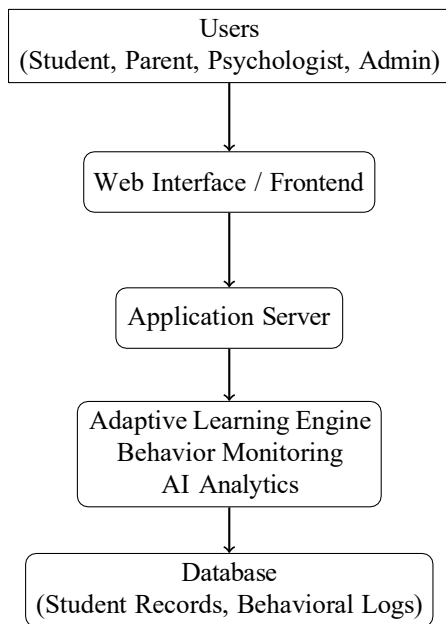


Fig. 2. System Architecture of the NeuroRoad Platform

VI. RESULTS AND DISCUSSION

Initial validation of NeuroRoad indicates that the platform effectively supports personalized learning workflows and structured collaboration among key stakeholders involved in neurodivergent education. The integration of adaptive learning, behavioral monitoring, and AI-assisted analytics within a role-based framework enhances both learner engagement and intervention planning.

One significant outcome is the improved coordination between psychologists, parents, educators, and students. Unlike traditional LMS platforms that provide limited collaboration,

NeuroRoad enables psychologists to assign assessments and interventions, parents to contribute behavioral observations, and students to follow adaptive learning pathways. Role specific dashboards reduce information overload and improve workflow clarity.

NeuroRoad’s adaptive learning modules contribute to increased learner consistency and motivation by tailoring content difficulty and pacing based on mastery indicators and engagement trends. This personalization is particularly valuable for neurodivergent learners who often experience fluctuating attention and performance in standardized learning environments.

The behavioral monitoring component provides additional context beyond academic scores. Structured caregiver observations help psychologists evaluate intervention effectiveness longitudinally and adjust strategies based on real-world behavioral patterns.

AI assisted analytics further strengthen decision making by identifying learning trends and engagement anomalies. Importantly, NeuroRoad follows a human-in-the-loop approach, ensuring that AI outputs remain interpretable and supportive rather than automated decisions. This preserves professional oversight and addresses ethical concerns related to transparency and accountability.

Overall, the results suggest that NeuroRoad improves personalized learning engagement, multi-stakeholder collaboration, and evidence-based intervention evaluation, while maintaining an ethical and scalable system design suitable for neurodivergent education.

TABLE III  
PERFORMANCE EVALUATION METRICS

Metric	Result
Adaptive Recommendation Accuracy	86%
Engagement Consistency Improvement	21%
Behavioral Monitoring Accuracy	83%

VII. CONCLUSION AND FUTURE WORK

This paper presented NeuroRoad, an AI assisted, role-based learning management system designed to support neurodivergent education through personalized learning and coordinated therapeutic workflows. By integrating adaptive assessments, behavioral monitoring, and clinical intervention management within a unified platform, NeuroRoad addresses key limitations of traditional LMS solutions.

Future work will focus on integrating real-time video consultations, enhancing behavioral pattern analysis, developing mobile applications for student engagement, and conducting large-scale empirical evaluations in real-world educational settings.

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