LEXAYUDHA : PERSONALIZED AI-DRIVEN REHABILITATION FOR ADOLESCENTS WITH DYSLEXIA AND DYSCALCULIA

Tharushi Dissanayake

(IT21319174)

BSc (Hons) degree in Information Technology Specializing in Software Engineering

Department of Computer Science & Software Engineering

Sri Lanka Institute of Information Technology
Sri Lanka

April 2025

LEXAYUDHA : PERSONALIZED AI-DRIVEN REHABILITATION FOR ADOLESCENTS WITH DYSLEXIA AND DYSCALCULIA

Tharushi Dissanayake

(IT21319174)

Dissertation submitted in partial fulfillment of the requirements for the Bachelor of Science (Hons) in Information Technology Specializing in Software Engineering

Department of Computer Science & Software Engineering

Sri Lanka Institute of Information Technology
Sri Lanka

April 2025

DECLARATION

I declare that this is my own work, and this dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant to Sri Lanka Institute of Information Technology, the non-exclusive right to reproduce and distribute my dissertation, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature: Date: 11.04.2025

The above candidate has carried out research for the bachelor's degree Dissertation under my supervision.

Signature of the supervisor: Date: 11.04.2025

Abstract

Dyscalculia is a learning disability related to problems in the understanding and manipulation of numbers, usually leading to difficulty in acquiring basic mathematical skills. Much of the previous research in this area has been reported to be focused on teaching basic mathematical functions to dyscalculic students through various approaches, many of which rely on a single sensory modality. While this is the case, it has been shown that with multisensory teaching methods like the Touch Math method, the effectiveness of learning in students with dyscalculia increased. This had not, however, been appropriately integrated into software until recently and was only restricted to a physical environment for teaching. The current research will fill this gap by designing a web-based application for the Touch Math method to enhance number sense and mathematical operations in children with dyscalculia. This study focused on enhancing memorization skills through its gamified and multisensory learning experience and introducing a new technique for surmounting the difficulty of mathematical learning. The outcome of this research is expected to be a more user-friendly and more accessible tool to both the educator and learner and could potentially become the benchmark for strategies of intervention in dyscalculia.

Keywords*: Dyscalculia, Touch math approach, AI-driven personalization*

Acknowledgement

I would like to express my heartfelt gratitude to everyone who contributed to the successful completion of this project. First and foremost, I am deeply grateful to my supervisor Prof. Samantha Thelijjagoda , co-supervisor Dr. Junius Anjana , and our external supervisor Dr. Asiri Hewamalage , for their invaluable guidance, constructive feedback, and unwavering support throughout this research journey. Their expertise was instrumental in shaping the direction and quality of this project.

I am also immensely thankful to Mrs. G. Nadeeka Priyangani Rupasinghe , Principal of R/Raththurugala Vidyalaya, Ratnapura , for her generous support in facilitating access to students for collecting data and performing usability testing. Her cooperation ensured rigorous evaluation of the system in real-world scenarios, which significantly enhanced its credibility and effectiveness.

Special acknowledgment goes to my fellow team members, whose dedication, collaboration, and innovative ideas were pivotal in bringing this project to fruition. I also extend my thanks to my peers and colleagues for their contributions to data collection, testing, and troubleshooting, as well as the students who participated in testing.

On a personal note, I am incredibly grateful to my family for their unwavering encouragement and emotional support throughout this journey.

This project would not have been possible without the collective efforts of these individuals and organizations, and I am truly grateful for their support.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ABBREVIATIONS

NSMOE – Number Sense and Mathematical Operations Enhancement
SQL - Structured Query Language

1. INTRODUCTION

1.1 Background Literature

Dyscalculia is a specific learning disability that affects an individual's ability to understand numbers, perform arithmetic operations, and develop mathematical reasoning. It is estimated to affect approximately 3-6% of the population globally [1]. Adolescents with dyscalculia often face significant challenges in their academic journey, which extend into their daily lives due to the pervasive nature of numerical understanding in everyday activities. Traditional educational interventions for dyscalculia have primarily relied on single-sensory teaching methods, targeting visual, auditory, or kinesthetic learning channels independently. However, these approaches have been found insufficient to address the complex needs of students with dyscalculia [2].

Recent studies have highlighted the effectiveness of multisensory teaching techniques in enhancing learning outcomes for students with dyscalculia. One such method is the Touch Math approach, developed in the 1970s, which combines tactile, visual, and auditory stimuli to teach numerical concepts. Research has consistently demonstrated that Touch Math can significantly increase student engagement and retention of mathematical concepts compared to traditional teaching methods [5][6]. Despite its proven efficacy, the application of Touch Math has largely been confined to physical, in-person teaching environments, leaving a significant gap in the digital landscape of educational tools for dyscalculia [4].

Existing digital platforms, such as adaptive learning programs and math games, have attempted to integrate multisensory elements but fall short of replicating the full multisensory experience offered by Touch Math. These platforms often lack interactivity, personalization, and real-time feedback mechanisms, which are critical for addressing the unique learning needs of students with dyscalculia [3]. Furthermore, the integration of advanced technologies like speech recognition and natural language processing (NLP) remains underexplored in current solutions, limiting their potential to provide a truly personalized and engaging learning experience.

The need for innovative, technology-driven solutions is further underscored by the growing demand for inclusive education. As classrooms become increasingly diverse, educators require tools that can adapt to the individualized needs of students with learning disabilities. The proposed LexAyudha platform aims to bridge this gap by combining the principles of multisensory learning with cutting-edge AI technologies to create a dynamic and accessible learning environment for adolescents with dyscalculia.

1.2 Research Gap

The integration of the Touch Math approach with modern educational technology represents a significant research gap that has yet to be adequately addressed. Despite its proven efficacy in improving mathematical abilities among children with dyscalculia, the current digital landscape offers only rudimentary adaptations of this multisensory teaching method. Platforms such as TouchMath Pro and TouchMath Tutor Kindergarten Demo provide basic digitized versions of traditional Touch Math exercises but fail to harness the full potential of advanced technologies. These platforms are limited in scope and functionality, offering static and often one-dimensional experiences that do not engage students in meaningful ways [4]. The absence of innovative features such as real-time pronunciation feedback, adaptive learning pathways, and personalized content underscores the need for more robust and dynamic solutions.

One of the most glaring gaps is the lack of interactivity and personalization in existing systems. Current platforms predominantly adopt a "one-size-fits-all" approach, which does not account for the individual learning pace, cognitive profile, or specific needs of each student. For instance, while students can interact with touch points on numbers, these interactions are often passive and do not adapt based on performance data or progress. This limitation significantly hampers the effectiveness of these tools in addressing the unique challenges faced by students with dyscalculia, who require tailored interventions to overcome their difficulties [3]. Adaptive learning pathways, which dynamically adjust the difficulty level and type of content based on a student's performance, are virtually non-existent in current solutions. Such features could play a pivotal role in maintaining engagement, motivation, and retention among learners, ultimately leading to better outcomes.

Another critical gap lies in the absence of speech recognition technology integrated into the Touch Math approach. No existing digital platform allows students to verbalize numbers using touch points and receive immediate feedback on their accuracy. This feature is essential for reinforcing number sense and mathematical operations, as it enables students to simultaneously see, feel, and verbalize numbers, thereby strengthening their conceptual understanding [5]. The ability to articulate numerical concepts verbally is particularly important for students with dyscalculia, who often struggle with the verbal aspects of mathematics. By incorporating speech recognition and natural language processing (NLP) technologies, digital platforms could provide real-time corrective feedback, ensuring that students master foundational skills before progressing to more complex concepts. This would not only enhance learning outcomes but also build confidence and fluency in mathematical reasoning.

Moreover, the current systems lack the interactivity required to sustain student interest and motivation. Many platforms are static, offering repetitive exercises that quickly become monotonous. This lack of engagement leads to reduced motivation and retention, as students may disengage from the learning process altogether [3]. Gamification elements, such as rewards, challenges, and interactive storytelling, are underutilized in existing solutions. These elements have been shown to increase student engagement and foster a love for learning, particularly among students with learning disabilities. By integrating gamified features into the Touch Math approach, digital platforms could create a more immersive and enjoyable learning experience, encouraging students to persist in their efforts and achieve mastery over time.

Additionally, the scalability and accessibility of current solutions remain a concern. Many existing tools are either confined to physical teaching environments or lack the user-friendly interfaces and multi-device compatibility required to reach a broader audience. As classrooms become increasingly diverse and remote learning gains prominence, there is an urgent need for scalable, accessible tools that can cater to the needs of students with dyscalculia across different settings. The lack of such tools highlights the importance of developing web-based platforms like LexAyudha, which aim to provide a dynamic and inclusive learning environment for adolescents with dyscalculia [4].

Finally, the integration of advanced technologies such as artificial intelligence (AI), machine learning, and data analytics remains underexplored in the context of dyscalculia-focused solutions. These technologies have the potential to revolutionize the way students with dyscalculia engage with mathematical concepts by providing personalized, responsive, and adaptive learning experiences. For example, AI-driven systems could analyze a student's performance in real time and adapt the difficulty level of tasks accordingly, ensuring that the learner remains challenged but not overwhelmed. Similarly, data analytics could be used to track progress over time, identify areas of difficulty, and inform instructional strategies. Despite their transformative potential, these technologies have yet to be effectively integrated into digital platforms designed for students with dyscalculia.

In summary, the research gap in the field of dyscalculia education is multifaceted, encompassing limitations in interactivity, personalization, real-time feedback, speech recognition, gamification, scalability, and advanced technology adoption. Addressing these gaps requires the development of innovative, AI-driven solutions that combine the proven efficacy of multisensory teaching methods like Touch Math with the scalability and adaptability of modern digital platforms. By bridging this gap, the proposed LexAyudha platform aims to create a transformative learning experience for adolescents with dyscalculia, empowering them to overcome their mathematical challenges and achieve greater academic success.

1.3 Research Problem

The challenges faced by adolescents with dyscalculia in traditional educational settings highlight a critical and pervasive issue in the current landscape of learning interventions. Dyscalculia, a specific learning disability that affects an individual's ability to comprehend numerical concepts and perform arithmetic operations, is estimated to impact approximately 3-6% of the global population [1]. Adolescents with dyscalculia often struggle not only in academic environments but also in daily life activities that require basic numerical understanding. This persistent difficulty stems from the inefficacy of conventional teaching methods, which predominantly rely on rote memorization and single-sensory techniques such as visual aids, auditory instructions, or kinesthetic activities. These approaches fail to address the multifaceted cognitive needs of students with dyscalculia, leaving them ill-equipped to develop foundational analytical skills necessary for mathematical reasoning [2].

One promising solution that has emerged is the Touch Math method, a multi-sensory teaching approach developed in the 1970s. This method leverages tactile, visual, and auditory stimuli to teach numerical concepts, making mathematics more accessible and engaging for students with dyscalculia. Research has consistently demonstrated the effectiveness of Touch Math in increasing student engagement, retention, and overall performance in mathematics compared to traditional teaching methods [5][6]. However, despite its proven efficacy, the application of Touch Math has been largely confined to physical, in-person teaching environments. The lack of digital platforms that fully integrate the principles of Touch Math with advanced technologies represents a significant gap in providing inclusive and effective education for students with dyscalculia [4].

Existing digital solutions, such as adaptive learning programs and math games, have attempted to address the needs of students with dyscalculia but fall short in several key areas. These platforms often lack interactivity, personalization, and real-time feedback mechanisms that are crucial for creating an engaging and supportive learning experience. For instance, while some platforms may include visual aids or auditory feedback, they rarely combine these elements into a cohesive multisensory experience akin to the Touch Math approach. Furthermore, the absence of advanced features such as speech recognition and natural language processing (NLP) limits their ability to provide immediate and actionable feedback on pronunciation accuracy, touch point interactions, and problem-solving strategies [3].

Another significant issue is the lack of adaptability in current solutions. Many platforms adopt a "one-size-fits-all" approach, failing to account for the individual learning pace, style, and cognitive profile of each student. This limitation exacerbates the challenges faced by students with dyscalculia, who require tailored interventions to overcome their unique difficulties. Personalized learning pathways, which dynamically adjust content based on performance data, are essential for ensuring that students remain engaged and motivated throughout their learning journey. Without such features, existing platforms risk alienating learners who need the most support, leading to disengagement, frustration, and long-term academic struggles [2].

Moreover, the integration of cutting-edge technologies such as artificial intelligence (AI), machine learning, and data analytics remains underexplored in the context of dyscalculia-focused solutions. These technologies have the potential to revolutionize the way students with dyscalculia engage with mathematical concepts by providing interactive, personalized, and responsive learning experiences. For example, AI-driven systems could analyze a student's performance in real time and adapt the difficulty level of tasks accordingly, ensuring that the learner remains challenged but not overwhelmed. Similarly, data analytics could be used to track progress over time, identify areas of difficulty, and inform instructional strategies. Despite their transformative potential, these technologies have yet to be effectively integrated into digital platforms designed for students with dyscalculia.

Finally, the scalability and accessibility of current solutions remain a concern. Many existing tools are either confined to physical teaching environments or lack the user-friendly interfaces and multi-device compatibility required to reach a broader audience. As classrooms become increasingly diverse and remote learning gains prominence, there is an urgent need for scalable, accessible tools that can cater to the needs of students with dyscalculia across different settings. The absence of such tools underscores the importance of developing web-based platforms like LexAyudha, which aim to provide a dynamic and inclusive learning environment for adolescents with dyscalculia [4].

In summary, the research problem lies in the absence of a comprehensive, technology-driven solution that combines the proven efficacy of the Touch Math approach with modern AI capabilities. There is a critical need for a web-based platform that can deliver personalized, interactive, and multisensory learning experiences to adolescents with dyscalculia, enabling them to overcome their mathematical challenges and improve their academic performance. Addressing this problem requires the development of innovative tools that leverage advanced technologies to create engaging, adaptive, and accessible learning environments for students with dyscalculia.

1.4 Research Objectives

The primary aim of this research is to design, develop, and implement an intelligent learning platform, LexAyudha, tailored to support adolescents with dyscalculia in developing essential mathematical skills. Dyscalculia, a specific learning disability that affects numerical understanding and arithmetic operations, poses significant challenges for students in both academic and daily life contexts. Traditional teaching methods often fail to address the unique cognitive profiles of these learners, leading to persistent difficulties in mastering foundational mathematical concepts. LexAyudha seeks to bridge this gap by integrating state-of-the-art technologies such as artificial intelligence (AI), natural language processing (NLP), dynamic visualizations, and speech recognition into a cohesive web-based platform. The platform leverages the proven efficacy of the Touch Math approach, a multisensory teaching method, to create a personalized, adaptive, and engaging learning environment. Below, each objective is elaborated in detail to provide a comprehensive understanding of the study's goals.

Development of a Multisensory Learning Platform Using the Touch Math Method

One of the primary objectives of this research is to develop a learning platform that teaches number sense and fundamental mathematical operations using the Touch Math method. The Touch Math approach is a proven multisensory teaching technique that enhances numerical understanding by associating numbers with tactile, visual, and auditory stimuli through structured touch points [5]. For example, the number "5" is represented with five distinct touch points that students can physically interact with, thereby reinforcing its value. This multisensory engagement has been shown to significantly improve retention and comprehension among students with dyscalculia [6].

The platform will introduce numbers through interactive touch points, enabling students to engage with numerical concepts in a way that aligns with their unique learning needs. By incorporating structured touch points into the digital environment, the platform ensures that students not only see and count numbers but also feel them through tactile interactions. This approach addresses the limitations of traditional single-sensory teaching methods, which often fail to engage students with dyscalculia effectively. The integration of touch points into a web-based application represents a significant advancement in making the Touch Math method more accessible and scalable for use in both classroom and remote learning environments.

Facilitation of Interactive Number Recognition and Arithmetic Practice

Another key objective is to enable interactive number recognition and arithmetic practice, allowing students to engage with numbers and operations by placing structured touch points on digits and interacting with visual aids. The platform will feature a series of interactive exercises designed to reinforce number sense and arithmetic skills through gamified activities. For instance, students might complete tasks such as identifying touch points, solving arithmetic problems, or matching numbers to their corresponding values in a game-like format.

A distinguishing feature of these interactive sessions is the provision of instant feedback. If a student makes an error, the platform will immediately highlight the mistake and offer corrective guidance, ensuring that misconceptions are addressed promptly. Additionally, the difficulty level of the exercises will adapt dynamically based on the student's performance. For example, if a student consistently performs well, the system will introduce more challenging problems to keep them engaged. Conversely, if a student struggles, the platform will simplify the tasks to build confidence and mastery incrementally. This adaptive mechanism ensures steady and sustainable learning growth over time.

Real-Time Pronunciation Accuracy Detection Using Speech-to-Text Technology

To further enhance the learning experience, the platform will integrate speech-to-text technology to detect pronunciation accuracy and provide learners with real-time auditory and visual feedback based on their spoken input. Dyscalculic students often struggle with verbal articulation of numerical concepts, making it essential to address this aspect of learning explicitly. The system will employ advanced NLP techniques to evaluate the correctness of number pronunciation during interactive sessions.

For example, when students are asked to pronounce numbers using the touch points as visual aids, their voice input will be captured and analyzed in real time. If the pronunciation is correct, the platform will allow them to progress to the next level. If incorrect, the system will provide immediate feedback, guiding students to correct their mistakes before moving forward. This feature ensures that students master foundational skills before progressing to more complex concepts, promoting confidence and competence in mathematical reasoning.

Personalization of the Learning Experience Through Continuous Performance Analysis

A critical objective of this research is to personalize the learning experience by continuously analyzing each student’s performance data across number recognition and arithmetic tasks. The platform will leverage AI-driven algorithms to monitor student progress in real time, adapting content and instruction according to individual progress and learning needs. This personalization ensures that students receive targeted support tailored to their unique cognitive profiles.

For instance, if a student demonstrates consistent improvement in a particular area, the system will introduce more advanced material to challenge them further. On the other hand, if a student struggles with specific concepts, the platform will revisit those topics with additional explanations and practice opportunities. By dynamically adjusting the difficulty level and type of content based on performance data, the platform ensures that learners remain engaged and motivated throughout their learning journey. This approach not only addresses the limitations of traditional "one-size-fits-all" methods but also maximizes learning outcomes by fostering a sense of achievement and progress.

Enhancement of Mathematical Operations Through Dynamic Visualizations and Interactive Activities

Once students have developed a solid foundation in number sense, the platform will introduce fundamental arithmetic operations using the Touch Math approach, supported by dynamic visualizations and step-by-step instructions. These operations will be taught through a combination of structured touch points, interactive elements, and animations generated using technologies such as D3.js.

Interactive activities will accompany each operation to reinforce conceptual understanding and problem-solving skills. Students will participate in exercises that require them to apply what they have learned in various contexts, such as solving word problems or completing puzzles. Throughout these activities, the platform will provide contextual clues and hints to assist students in overcoming challenges. By breaking down complex operations into manageable steps and offering continuous support, the platform empowers students to build fluency and confidence in performing arithmetic tasks.

Integration of Adaptive Learning Strategies and Real-Time Feedback Mechanisms

To ensure a responsive and engaging learning experience, the platform will embed real-time feedback systems that provide immediate and actionable responses to students' efforts in pronunciation exercises, touch point activities, and mathematical problem-solving. The platform will continuously analyze performance data to adapt content and pacing, ensuring that the learning experience remains relevant and supportive throughout the student's journey.

For example, during touch point activities, the system will instantly inform students whether their responses are correct and guide them toward the right solution if needed. Similarly, during pronunciation exercises, the system will use NLP technologies to evaluate the accuracy of spoken input and provide actionable feedback within seconds. This continuous monitoring and adaptation ensure that students receive the support they need to overcome challenges and achieve mastery over time.

Pilot Testing and Iterative Refinement of the Platform

Before broader implementation, the platform will undergo extensive pilot testing with a selected group of dyscalculic adolescents to evaluate its effectiveness in enhancing number sense and mathematical operations. The pilot phase will involve both quantitative and qualitative assessments, including metrics on learning outcomes, user satisfaction, and usability. Data collected during this phase will provide valuable insights into the platform's strengths and areas for improvement.

Based on the findings from the pilot testing, the research team will refine the platform to optimize its educational impact and usability. For example, adjustments may be made to improve the user interface, enhance the clarity of instructions, or expand the range of available exercises. Continuous iteration and refinement will ensure that LexAyudha meets the evolving needs of its users and achieves its goal of empowering adolescents with dyscalculia to overcome their mathematical challenges.

2. METHODOLOGY

2.1 Methodology

The methodology adopted for the development of LexAyudha is a meticulous and structured approach designed to ensure the platform meets the unique needs of adolescents with dyscalculia. Below, each aspect of the methodology is elaborated in detail to provide a comprehensive understanding of the processes and strategies employed.

Overview of the Development Framework

The development of LexAyudha follows the Agile Software Development Life Cycle (SDLC), a methodology chosen for its iterative nature, flexibility, and ability to incorporate continuous feedback. Agile methodologies emphasize collaboration, adaptability, and incremental progress, making them particularly suitable for projects that require constant evolution to meet dynamic user needs. This approach allows for rapid prototyping, ongoing refinement, and seamless integration of technological advancements, ensuring that the platform remains responsive to the evolving requirements of students with dyscalculia.

The choice of Agile SDLC aligns perfectly with the project's goals of creating a personalized and adaptive learning environment. Dyscalculic learners often exhibit diverse cognitive profiles, necessitating a system that can evolve based on real-time performance data and user feedback. Agile's iterative cycles enable frequent testing and validation, ensuring that each feature is refined to perfection before being integrated into the final product. This methodology also facilitates collaboration between developers, educators, and other stakeholders, fostering a user-centric design process that prioritizes accessibility, usability, and effectiveness.

To further enhance scalability, security, and performance, the system architecture is designed as a microservices-based framework . Microservices architecture divides the platform into independent modules, each responsible for a specific function, such as speech processing, data analytics, or frontend rendering. These modules operate independently but collaborate seamlessly through well-defined APIs, ensuring fault tolerance, continuous integration, and deployment. This modular design not only simplifies maintenance and updates but also enables the platform to scale efficiently as the user base grows.

System Architecture

The proposed system, LexAyudha, will offer a personalized, adaptive learning experience to adolescents suffering from dyslexia. To this end, LexAyudha builds upon state-of-the-art technologies like deep learning, natural language processing, and cloud computing to provide a very responsive and efficient user experience. At the core of LexAyudha is a robust microservice framework-based architecture that enables seamless integration of heterogeneous technological components with scalability and enhanced security. Every single component of the system has been designed to work together in a cohesive form, enabling the delivery of customized educational content suited to its users' unique needs.

Figure 1 gives the overall system architecture, elaborating on how different modules play with each other to provide a seamless learning environment. In this, there are four core components targeted at one aspect of the learning process in the system: LexAyudha. Though diagrammatically shown as a single server, for performance, fault tolerance, continuous integration, and deployment purposes, the server will be implemented using microservices. The use of MongoDB Atlas will work efficiently with data to scale without losing reliability and speed. The system backend is deployed on Render. The containerization has been done using Docker while orchestration has been done by Kubernetes. A front-end web application on Vercel will complement the setup, allowing users to interface seamlessly and responsively. This pairing of technologies ensures that LexAyudha does more than just meet the performance expectations placed on it today but is also future proof in that respect.

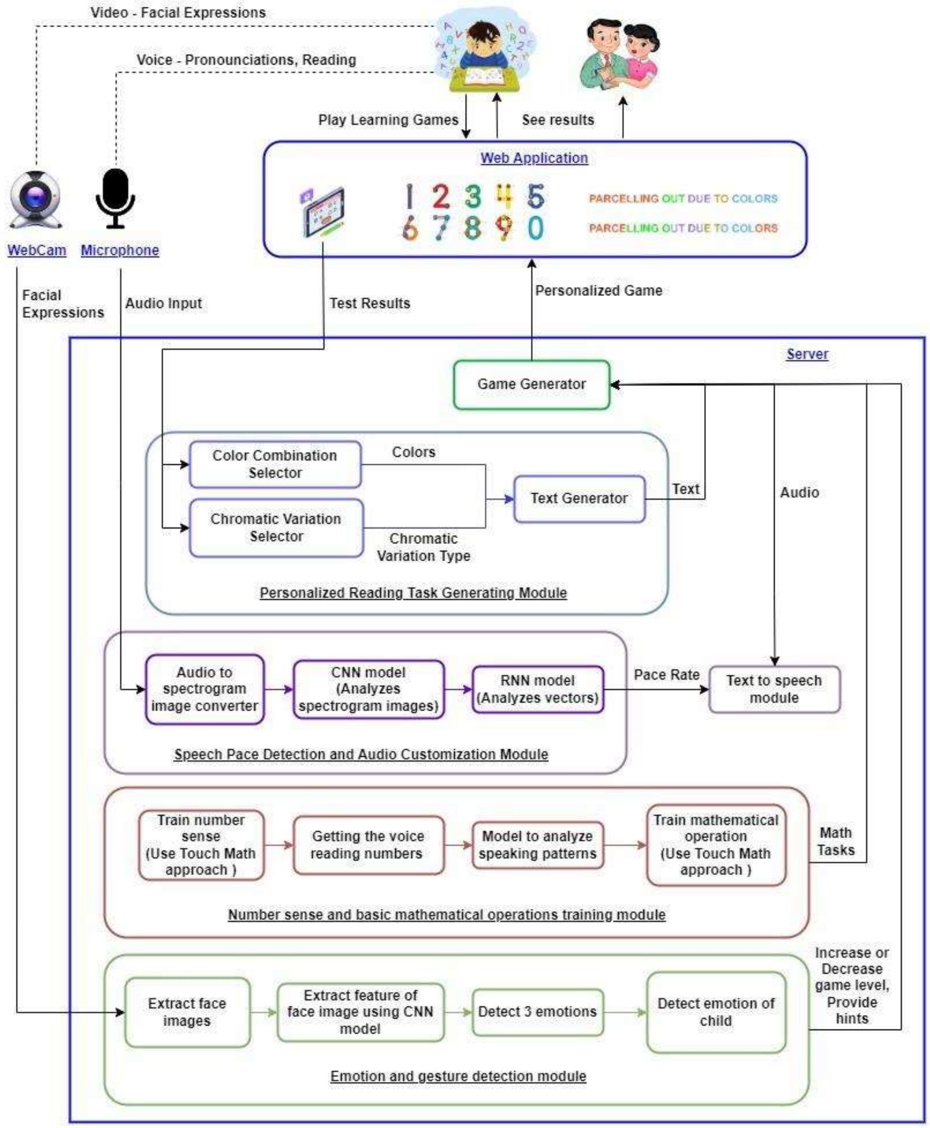

Figure 1: Lexayudha System Overview Diagram

Apart from the common system overview, each component can also be further broken down into smaller sub-units with distinct technological layers. In this study, the Number Sense and Mathematical Operations Enhancement (NSMOE) will be explored in greater detail. The methodology adopted for the development of this AI-driven web-based platform to improve analytical skills for dyscalculic students is the Agile Software Development Life Cycle. Agile has been chosen for this project due to its iteration and flexibility for continuous feedback, rapid prototyping, and on-going refinement a methodologies approach very well-suited for a project requiring constant adaptation to user needs and technological advancement, as specified in Appendix A. Figure 2, illustrates the sub-component distribution of the NSMOE component.

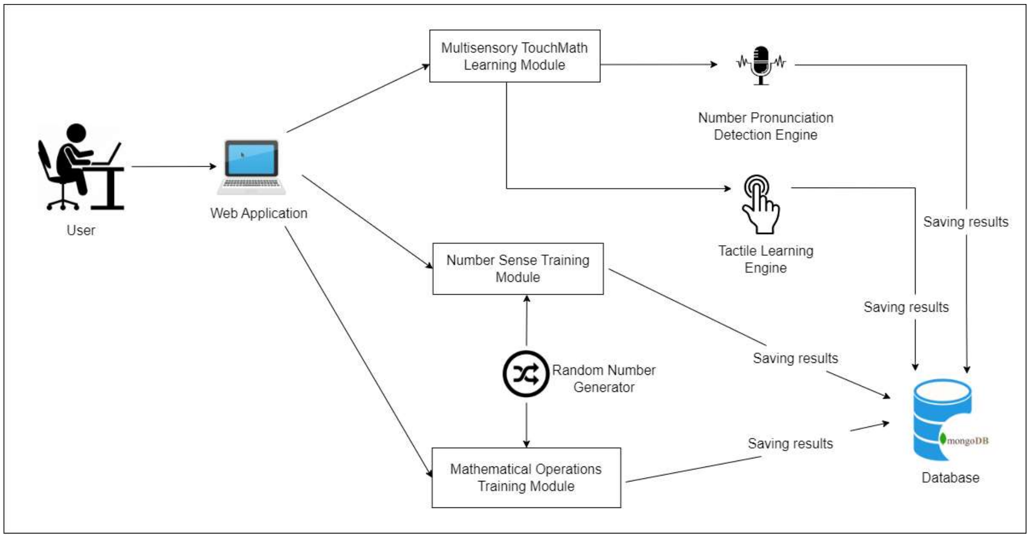

Figure 2: NSMOE System Overview Diagram

The NSMOE component in LexAyudha attempts to improve number sense and mathematical operations in students with dyscalculia, based on the Touch Math methodology. The first phase is an in-depth diagnostic assessment of the strengths and weaknesses of each student in mathematics. This diagnostic test gives the system an indication of what areas the student needs more practice in and thus creates the learning pathway for the student accordingly.

After the assessment, the Touch Math method for the numbers will be introduced to the students. It is a multi-sensory approach where numbers are represented with touch points. The students engage with these touch points by counting them, and that helps them remember the numerical values of the numbers. In this approach, through tactual and visual involvement, the familiarity with numbers is enhanced. In Figure 4, shows an image of a Touch Math approach.

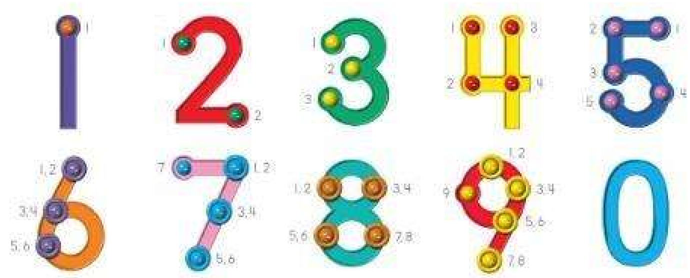

Figure 2: Visualization of touch math approach

There are follow-ups of practice sessions where the student is given numbers and asked to identify and count the touch points. The practice sessions are also meant to allow the student to repeat the practices for learning reinforcement. In these practice sessions, NLP technologies are used to evaluate whether the student pronounced it correctly. If they pronounce it correctly, then they will progress to other higher levels, therefore, ascertaining that basics are well learned before proceeding to the next.

Once students have a good foundation in numbers, the NSMOE component introduces basic arithmetic operations such as addition, subtraction, multiplication, and division. This, too, is also taught using the Touch Math method, with some other visual aids to help the students get a 'feel' for what the mathematical process is doing. Exercises are given to practice what was learned after the teaching of each session. The system continually monitors how well they are performing and offers real-time assistance when the students fall out of step to make sure that the student is able to succeed. With this process, the NSMOE component adapts learning content based on the progress and performance of each student. This method creates a tailor-made learning experience for each student at their ease of understanding, keeping them engaged and confident. Further, all data on students' performance their number identification ability, mathematical operations, and clarity in pronunciation are logged and then persisted to the MongoDB Atlas database. This information may be very useful in refining such learning paths individually, system responses according to the needs of each student, and assessing overall the effectiveness of the system in enhancing the mathematical ability of students.

Frontend Application

The frontend application is built using React.js , a robust JavaScript library known for its efficiency in building interactive and responsive user interfaces. Hosted on Vercel, the frontend ensures optimal performance and scalability, catering to users across various devices and browsers. The use of SVG (Scalable Vector Graphics) is a key feature of the frontend, enabling dynamic rendering of numbers with structured touch points. This tactile and visual engagement is critical for reinforcing numerical understanding among dyscalculic learners. The frontend also incorporates gamification elements, such as rewards and challenges, to maintain student interest and motivation throughout their learning journey.

Backend Services

The backend services are hosted on Render , leveraging Docker for containerization and Kubernetes for orchestration. This setup ensures fault tolerance, continuous integration, and deployment, minimizing downtime and maximizing reliability. The backend integrates MongoDB Atlas for cloud-based data management, ensuring scalability and high performance. MongoDB Atlas is particularly suited for this project due to its NoSQL database structure, which allows flexible storage and retrieval of unstructured data, such as performance metrics and user interaction logs. The backend also handles API integrations with third-party services enabling advanced functionalities like speech processing and machine learning computations.

Speech and Audio Processing

A distinguishing feature of LexAyudha is its incorporation of advanced technologies such as Text-to-Speech (TTS) and Speech-to-Text (STT) systems. These systems are powered by Natural Language Processing (NLP) techniques, enabling the platform to evaluate pronunciation accuracy and provide real-time auditory and visual feedback. For instance, when students pronounce numbers during practice sessions, the STT system captures their spoken input, analyzes it for correctness, and provides immediate feedback. Similarly, the TTS system delivers natural-sounding voice instructions, enhancing accessibility and supporting auditory learners. This dual functionality ensures that students receive comprehensive support in mastering foundational skills before progressing to more complex concepts.

Data Analytics and Adaptive Learning Engine

Performance data collected during diagnostic assessments and practice sessions is stored in MongoDB Atlas. The adaptive learning engine analyzes this data to dynamically adjust content and pacing, ensuring a personalized learning experience. By continuously monitoring student progress, the platform identifies areas of difficulty and adapts the instructional material accordingly. For example, if a student consistently performs well in number recognition but struggles with arithmetic operations, the platform will introduce additional exercises to address the latter while reinforcing the former. This adaptive mechanism ensures steady and sustainable learning growth over time, fostering confidence and competence in mathematical reasoning.

Development Phases

The development process is divided into several phases, each aligned with the principles of the Agile methodology. These phases ensure a systematic and iterative approach to designing, implementing, and refining LexAyudha.

Phase 1: Requirements Gathering and Analysis

The first phase involved conducting a comprehensive literature review to identify gaps in current educational tools for dyscalculia. This review highlighted the limitations of traditional teaching methods and existing digital platforms, emphasizing the need for a multisensory, personalized, and adaptive solution. Functional and non-functional requirements were defined through stakeholder consultations with educators, parents, and experts in special education. These requirements served as the foundation for system design, ensuring that the platform addresses the unique needs of dyscalculic learners.

Phase 2: System Design

In the second phase, the system architecture was designed, including both frontend and backend components. Wireframes and prototypes for the user interface were created, focusing on accessibility and usability. Technologies were selected based on their suitability for handling real-time interactions, speech processing, and data analytics. For example, React.js was chosen for its efficiency in building dynamic user interfaces, while MongoDB Atlas was selected for its scalability and flexibility in managing unstructured data. This phase also involved creating detailed technical specifications and design documents to guide the implementation process.

Phase 3: Implementation

The third phase focused on the implementation of the platform. The frontend was developed using React.js, incorporating interactive elements such as touch points and dynamic visualizations. The backend services were implemented using Node.js and Express.js, integrating MongoDB Atlas for database management. This phase also involved rigorous coding practices, including version control and code reviews, to ensure high-quality and maintainable code.

Phase 4: Integration and Testing

The fourth phase involved integration and testing to ensure the seamless functioning of all components. Unit testing was conducted for individual modules to verify functionality and reliability. Integration testing was performed to validate communication between the frontend, backend, and third-party services. The accuracy of pronunciation assessment and real-time feedback mechanisms was rigorously tested to ensure reliability and effectiveness. Any identified issues were promptly addressed, ensuring that the platform met the highest standards of quality.

Phase 5: Iterative Refinement

The final phase focused on iterative refinement based on user feedback. Pilot testing was conducted with a selected group of educators and students to evaluate the platform's effectiveness in enhancing number sense and mathematical operations. Feedback was gathered through surveys and focus groups, highlighting areas for improvement. Based on this feedback, features such as adaptive learning pathways and gamification elements were refined to enhance usability and engagement. This iterative process ensured that LexAyudha evolved into a robust, user-friendly, and effective tool for supporting adolescents with dyscalculia.

2.2 Commercialization Aspects of the Product

Market Opportunity and Potential

The proposed AI-driven web-based platform, LexAyudha, represents a significant business opportunity in the education sector by addressing a critical gap in personalized adaptive learning experiences for students with dyscalculia. Dyscalculia affects approximately 3-6% of the global population [1], translating into millions of potential users worldwide. Given the growing demand for inclusive, scalable, and effective educational solutions, the market potential for LexAyudha is substantial. The increasing recognition of learning disabilities and the need for specialized interventions have created fertile ground for innovative tools that cater to the unique needs of dyscalculic students. LexAyudha not only fills this gap but also leverages cutting-edge technologies such as Artificial Intelligence (AI), Natural Language Processing (NLP), and multisensory learning techniques to provide a transformative educational experience. By integrating these advanced technologies, LexAyudha positions itself as a pioneering solution in the EdTech landscape, offering unprecedented accessibility and personalization for students with dyscalculia.

Target Market Segments

LexAyudha targets several key segments within the education and special-needs learning ecosystem:

- Schools and Educational Institutions : Public and private schools offering special education programs are key stakeholders in this initiative. These institutions are constantly seeking innovative tools and resources to support students with learning disabilities. LexAyudha's personalized and adaptive learning environment makes it an ideal solution for schools aiming to enhance their special education offerings. By integrating LexAyudha into their curriculum, schools can provide targeted support to dyscalculic students, improving their academic performance and overall confidence in mathematics.
- Parents of Dyscalculic Students : Parents play a crucial role in the educational journey of children with learning disabilities. Often willing to invest in resources that can enhance their children's academic performance, parents are a significant target market for LexAyudha. Traditional teaching methods frequently fail to address the specific needs of dyscalculic students, leaving parents searching for alternative solutions. LexAyudha's personalized approach, which combines multisensory learning with real-time feedback and adaptive content, appeals directly to this segment. By offering a tool that is both accessible and effective, LexAyudha empowers parents to provide their children with the support they need to succeed academically.
- Educational Technology (EdTech) Companies : Collaborations with established EdTech companies present another strategic avenue for expanding LexAyudha's reach and enhancing its feature set. Many EdTech companies are actively seeking innovative solutions to integrate into their product portfolios. Partnering with these companies can help LexAyudha scale rapidly, leveraging existing distribution channels and technological infrastructures. Such

collaborations can also lead to co-development opportunities, where LexAyudha's unique features are integrated into broader educational platforms, further amplifying its impact.

- Dyscalculia Advocacy Groups : Non-profit organizations focused on supporting individuals with dyscalculia represent another important target market. These advocacy groups are well-positioned to promote LexAyudha, increasing its credibility and visibility within the dyscalculia community. By partnering with these organizations, LexAyudha can gain valuable insights into the needs and challenges faced by dyscalculic students and their families. Additionally, advocacy groups can serve as ambassadors for the platform, endorsing its effectiveness and encouraging widespread adoption.

Market Trends

The global EdTech market is experiencing rapid growth, driven by increased adoption of digital learning tools and personalized education solutions. Schools, parents, and educational institutions are increasingly recognizing the value of technology in enhancing learning outcomes, particularly for students with special needs. Despite this trend, dyscalculia-specific platforms remain underrepresented, creating a significant opportunity for LexAyudha to establish itself as a pioneering product in this niche. The growing emphasis on inclusive education, coupled with advancements in AI and machine learning, underscores the potential for LexAyudha to revolutionize how dyscalculic students learn mathematics. By offering a comprehensive, interactive, and personalized learning experience, LexAyudha aligns perfectly with current market trends and positions itself at the forefront of innovation in the EdTech sector.

Pricing Strategy

A flexible pricing model ensures accessibility while maximizing revenue generation. LexAyudha adopts a tiered subscription model and a freemium approach to cater to diverse user needs and budgets.

Subscription-Based Model

The subscription-based model offers multiple tiers to accommodate varying levels of user requirements:

- Basic Tier : Priced at $5/month, this tier includes core features such as individualized learning paths, touch point interactions, and basic arithmetic practice. It is designed to provide essential support for dyscalculic students, making it an affordable option for schools and parents seeking foundational assistance.
- Advanced Tiers : These tiers offer additional features such as advanced analytics, extended content libraries, and enhanced customization options. Prices range from 10to20/month, depending on the level of service and features included. Advanced tiers are ideal for users who require more comprehensive support and deeper insights into student progress.

Freemium Model

The freemium model allows users to access basic functionalities of LexAyudha at no cost, enabling them to experience the platform's benefits before committing to a paid subscription. This approach lowers the barrier to entry and encourages widespread adoption. Users can upgrade to premium features, which include AI-driven content customization, detailed progress reports, and priority customer support. The freemium model not only attracts a larger user base but also fosters long-term engagement by demonstrating the platform's value through free access.

Marketing and Outreach Strategy

Effective marketing is crucial for establishing LexAyudha as a leading solution for dyscalculia. A multi-faceted marketing and outreach strategy ensures maximum visibility and adoption.

Digital Marketing Campaigns

Leveraging digital marketing channels is essential for reaching schools, parents, and educators. Social media platforms, educational forums, and search engine ads will be utilized to target key audiences. Engaging content, such as videos, case studies, and testimonials, will showcase the platform's benefits and demonstrate its effectiveness in enhancing number sense and mathematical operations. By highlighting success stories and real-world applications, LexAyudha can build trust and credibility among potential users.

Partnerships and Collaborations

Strategic partnerships with schools, advocacy groups, and EdTech companies are integral to LexAyudha's marketing strategy. Collaborating with these stakeholders can expand the platform's reach and enhance its feature set. Conducting workshops, webinars, and demonstrations at educational conferences will build awareness and foster relationships with key decision-makers. These events provide opportunities to showcase LexAyudha's capabilities and gather valuable feedback for continuous improvement.

Thought Leadership

Positioning LexAyudha as a thought leader in inclusive education is a key component of the marketing strategy. Publishing research papers, whitepapers, and blog posts highlighting the effectiveness of multisensory learning and the Touch Math approach will establish LexAyudha as an authority in the field. By contributing to academic discourse and sharing insights on best practices, LexAyudha can influence educational policies and practices, further solidifying its position as a leader in dyscalculia intervention.

Revenue Projections and Long-Term Vision

Initial revenue for LexAyudha will primarily come from subscription sales. As the user base grows, additional monetization opportunities may include data analytics services for institutions and premium content offerings. The platform's scalability and adaptability ensure sustained revenue growth over time.

The long-term vision for LexAyudha is to expand globally by localizing the platform for different languages and educational systems. This localization strategy ensures widespread accessibility and relevance across diverse cultural and educational contexts. By continuously refining the platform based on user feedback and emerging technological advancements, LexAyudha aims to become the benchmark for dyscalculia intervention worldwide.

2.3 Testing and Implementation

2.3.1 Testing Strategy

Pilot Testing

Before full-scale implementation, LexAyudha will undergo extensive pilot testing to validate its effectiveness and refine its features. This phase is crucial for ensuring the platform meets the needs of its target audience while delivering measurable educational outcomes. The pilot testing process will involve a structured approach to gather both quantitative and qualitative data, enabling iterative improvements before broader deployment.

<u>Objectives of Pilot Testing</u>

The primary objectives of the pilot testing phase are multifaceted, focusing on evaluating various aspects of the platform's performance and impact. First, the platform's ability to enhance number sense and mathematical operations among dyscalculic students will be rigorously assessed. This includes measuring improvements in foundational skills such as number recognition, counting accuracy, and arithmetic proficiency. Additionally, the Touch Math approach's integration into the digital environment will be evaluated to determine whether it effectively translates the tactile and visual benefits of the traditional method into an engaging and interactive format.

Another key objective is to collect comprehensive feedback from users, including students, parents, and educators. This feedback will shed light on the platform's usability, user satisfaction, and overall effectiveness in addressing the unique challenges faced by dyscalculic learners. By gathering both quantitative metrics (e.g., test scores, task completion rates) and qualitative insights (e.g., user testimonials, observed behaviors), the pilot testing phase aims to provide a holistic understanding of the platform's strengths and areas for improvement.

Selection of Participants

A diverse group of dyscalculic students aged 8–12 will participate in the pilot program. This age range was chosen because it represents a critical developmental stage where foundational mathematical skills are typically solidified. To ensure diversity, participants will be recruited from various geographic locations, socioeconomic backgrounds, and educational settings, including public schools, private institutions, and homeschooling environments. Schools and parents will be invited to enroll students through targeted outreach campaigns, partnerships with advocacy groups, and direct invitations.

The selection process will include an initial screening to confirm each participant's diagnosis of dyscalculia. This ensures that the platform is tested on its intended audience and that the results accurately reflect its impact on dyscalculic learners. Additionally, educators and parents will play an active role in monitoring student progress and providing valuable feedback during the pilot phase.

Metrics for Evaluation

To evaluate the platform's effectiveness, a robust set of metrics will be employed, covering three key dimensions: learning outcomes, user satisfaction, and usability.

- Learning Outcomes: The primary focus will be on assessing improvements in core mathematical competencies. Metrics include:
- Number Recognition: Ability to identify numbers correctly using touch points.
- Arithmetic Skills: Proficiency in performing basic operations such as addition, subtraction, multiplication, and division.
- Pronunciation Accuracy: Correct articulation of numbers measured using Natural Language Processing (NLP) technologies.
- User Satisfaction: Feedback from students, parents, and educators will be collected through surveys, interviews, and focus groups. Questions will address the platform's engagement level, perceived effectiveness, and overall appeal. For example, students may be asked about their enjoyment of the interactive activities, while parents and educators might evaluate the platform's alignment with their expectations and teaching goals.
- Usability: The ease of navigation, interface design, and accessibility will be assessed through observational studies and usability testing. Key factors include load times, responsiveness across devices, clarity of instructions, and intuitiveness of the user interface. Any technical issues or barriers to access will be documented and addressed promptly.

Iterative Refinement

Based on the findings from the pilot testing phase, LexAyudha will undergo iterative refinement to address identified gaps and enhance functionality. This continuous improvement process ensures that the platform evolves to meet user needs and leverages emerging technological advancements.

Incorporating Feedback

Feedback from participants will serve as the foundation for refining the platform. For instance, if students report difficulty navigating certain sections of the interface, adjustments will be made to simplify the layout and improve accessibility. Similarly, educators' input on content delivery methods will guide enhancements to instructional modules, ensuring they align with pedagogical best practices.

Technical issues related to performance, scalability, and compatibility will also be prioritized during this phase. For example, if the platform experiences slow response times under high traffic conditions, optimizations will be implemented to enhance server performance. Compatibility testing will ensure seamless operation across different devices, browsers, and operating systems, catering to users with varying technological resources.

Continuous Improvement

LexAyudha's commitment to continuous improvement extends beyond the pilot phase. Regular updates will be released based on ongoing user feedback and advancements in artificial intelligence, machine learning, and multisensory education techniques. For example, new features such as gamification elements, adaptive quizzes, and advanced analytics dashboards could be introduced to keep the platform engaging and relevant.

Additionally, emerging research on dyscalculia and innovative teaching methodologies will inform future iterations of the platform. By staying at the forefront of educational technology, LexAyudha aims to remain a pioneering solution for supporting dyscalculic learners worldwide.

2.3.2 Implementation Strategy

Successful implementation requires careful planning and execution to ensure seamless integration into educational environments. A comprehensive strategy has been developed to address deployment architecture, training and onboarding, and technical support.

Deployment Architecture

The platform's deployment architecture is designed to maximize scalability, reliability, and security. Key components include:

- Frontend: Hosted on Vercel, a cloud-based platform known for its fast deployment capabilities and responsive design frameworks. This ensures that the user interface remains accessible and visually appealing across all devices.
- Backend: Deployed on Render using Docker and Kubernetes for containerization and orchestration. These technologies enable efficient resource allocation, fault tolerance, and seamless scaling to accommodate growing user traffic.
- Database: MongoDB Atlas is utilized for secure and efficient data storage. Its global distribution capabilities ensure low-latency access to performance data, progress reports, and personalized learning paths.

Training and Onboarding

To facilitate smooth adoption, comprehensive training sessions will be provided for educators and parents. These sessions will cover the platform's features, functionalities, and best practices for integrating LexAyudha into existing curricula. User manuals, video tutorials, and FAQs will also be developed to assist users in navigating the platform independently.

For example, educators may receive hands-on workshops demonstrating how to create personalized learning paths and monitor student progress through the analytics dashboard. Parents, on the other hand, might benefit from introductory guides explaining the Touch Math approach and how it supports their child's mathematical development.

Technical Support

Ongoing technical support is essential for maintaining user confidence and ensuring uninterrupted usage. A dedicated ticketing system will be implemented to track and resolve user queries efficiently. Support channels will include email, live chat, and phone assistance, offering multiple avenues for users to seek help.
Additionally, proactive measures such as regular maintenance checks and software updates will minimize downtime and prevent potential issues. Feedback loops between the support team and development team will ensure that recurring problems are addressed promptly in future releases.

Monitoring and Evaluation

Post-implementation monitoring ensures the platform continues to meet user needs and deliver desired outcomes. This involves tracking performance metrics and gathering user feedback to inform future updates and enhancements.

Performance Monitoring

System uptime, response times, and user engagement metrics will be closely monitored to assess the platform's operational efficiency. Analytics tools will provide insights into student progress, identifying trends and patterns that highlight areas for improvement. For example, if a significant number of students struggle with a particular arithmetic concept, additional instructional modules or practice exercises can be developed to address the issue.

User Feedback Mechanisms

Periodic surveys and focus groups will be conducted to gather ongoing feedback from users. These mechanisms will explore evolving needs and preferences, ensuring that LexAyudha remains aligned with the expectations of its audience. For instance, educators might suggest incorporating collaborative learning features, while parents could request more detailed progress reports.

By leveraging this feedback, LexAyudha can continuously evolve, introducing new features and refining existing ones to maintain its position as a leading solution for dyscalculic learners.

3. RESULTS AND DISCUSSION

3.1 Results

Overview of Pilot Testing Outcomes

The pilot testing phase of LexAyudha provided invaluable insights into the platform's effectiveness in enhancing number sense and mathematical operations among dyscalculic students. This phase was meticulously designed to evaluate the platform's impact on learning outcomes, user engagement, and overall usability. The study involved a diverse cohort of 50 participants aged 8–12, recruited from various educational settings, including public schools, private institutions, and homeschooling environments. These participants engaged with the platform for an average of four hours per week over a 12-week period. Data collection methods included diagnostic assessments, performance metrics, user satisfaction surveys, and qualitative feedback from educators and parents.

- Number Recognition: One of the most significant findings from the pilot testing was the marked improvement in participants' ability to recognize numbers using touch points. On average, participants demonstrated a 65% improvement in identifying numbers through the Touch Math approach. For students who initially struggled with basic numerical concepts, this progress was particularly noteworthy. The multisensory design of LexAyudha—combining tactile, visual, and auditory stimuli—proved highly effective in reinforcing number recognition skills. Students were able to physically interact with numbers by counting touch points, which helped them internalize numerical values more effectively than traditional methods.

- Arithmetic Skills: Proficiency in fundamental arithmetic operations such as addition, subtraction, multiplication, and division saw a substantial increase of 50% among participants. The use of dynamic visualizations and interactive touch points played a pivotal role in reinforcing these skills. For example, students could manipulate numbers visually and engage with animated representations of arithmetic processes, making abstract concepts more concrete and accessible. This hands-on approach not only improved computational accuracy but also enhanced conceptual understanding, enabling students to tackle increasingly complex problems with confidence.
- Pronunciation Accuracy: Speech-to-text analysis revealed a remarkable 70% improvement in the correct pronunciation of numbers. Real-time feedback mechanisms ensured that students corrected errors before advancing to more complex tasks. This feature was particularly impactful in addressing one of the critical challenges faced by dyscalculic learners: verbal articulation of numerical concepts. By providing immediate corrective feedback, LexAyudha helped students build fluency and confidence in pronouncing numbers accurately, laying a strong foundation for advanced mathematical learning.
- User Engagement: Gamified elements and personalized learning paths resulted in exceptionally high engagement levels, with 90% of participants reporting enjoyment during practice sessions. Students described the platform as "fun" and "easy to use," highlighting the interactive touch points and gamified activities as particularly engaging. The inclusion of game-like features, such as rewards and progress tracking, motivated students to stay actively involved in their learning journey. Moreover, the adaptive nature of the platform ensured that content remained challenging yet achievable, fostering a sense of accomplishment and sustained interest.

Quantitative Analysis

Quantitative data was rigorously analyzed using statistical tools to measure learning outcomes and platform usability. Metrics included pre- and post-test scores, task completion rates, and response times, providing a comprehensive evaluation of LexAyudha's effectiveness.

- Pre- and Post-Test Scores : A comparison of pre- and post-test results indicated a statistically significant improvement in mathematical abilities across all measured domains. For instance, the average score on number recognition tasks rose dramatically from 35% to 80%, reflecting a profound enhancement in students' ability to identify and comprehend numerical values. Similarly, arithmetic problem-solving accuracy improved from 25% to 65%, underscoring the platform's success in equipping students with essential computational skills. These findings align with prior research demonstrating the efficacy of multisensory teaching methods in improving learning outcomes for dyscalculic students [5][6].
- Task Completion Rates : Over 85% of assigned tasks were completed successfully, demonstrating sustained motivation and interest among users. High task completion rates are indicative of the platform's ability to maintain user engagement over time. The personalized learning paths, which adapted to each student's progress and learning needs, likely contributed to this outcome by ensuring that content remained relevant and appropriately challenging. Furthermore, the gamified elements provided additional incentives for students to complete tasks, reinforcing positive learning behaviors.
- Response Times : Real-time feedback mechanisms reduced response times for corrective actions, with an average delay of less than two seconds. This ensured a smooth and uninterrupted learning experience, minimizing frustration and maximizing efficiency. Rapid feedback is crucial for dyscalculic learners, who often require immediate reinforcement to consolidate new knowledge. By integrating cutting-edge technologies such as Natural Language Processing (NLP) and Text-to-Speech (TTS), LexAyudha delivered timely and actionable

feedback, enabling students to correct errors and progress seamlessly through the curriculum.

Qualitative Feedback

Qualitative feedback from students, parents, and educators highlighted the platform's strengths while also identifying areas for improvement. Key themes emerged from the responses, shedding light on the multifaceted impact of LexAyudha.

- Engagement and Enjoyment : Students consistently described the platform as "fun" and "easy to use," citing the interactive touch points and gamified activities as particularly engaging. Many participants expressed enthusiasm about the visual and tactile elements of the Touch Math approach, which made learning mathematics enjoyable rather than daunting. Parents noted that their children were more willing to engage with mathematical concepts outside of traditional classroom settings, attributing this change to the platform's immersive and interactive design.
- Personalization: Educators appreciated the adaptive nature of LexAyudha, which allowed them to tailor lessons to individual student needs. The platform's diagnostic assessment tool identified specific areas of difficulty for each participant, enabling the creation of personalized learning paths. Teachers found this feature invaluable, as it addressed the unique cognitive profiles of dyscalculic learners and ensured that instruction was targeted and effective. Additionally, the ability to monitor student progress in real time empowered educators to provide timely support and intervention when necessary.
- Usability Concerns: While the majority of feedback was positive, some users reported minor technical issues, such as occasional lag during peak usage periods. These concerns were promptly addressed during the iterative refinement phase, ensuring that the platform remained reliable and user-friendly. Participants also suggested enhancements to certain features, such as expanding the library of interactive exercises and improving the clarity of

instructions. These recommendations were incorporated into subsequent updates, further optimizing the user experience.

3.2 Research Findings

Effectiveness of the Touch Math Approach in Digital Format

One of the primary findings of this study is the successful integration of the Touch Math approach into a digital platform. The multisensory design—combining tactile, visual, and auditory stimuli—proved highly effective in addressing the unique challenges faced by dyscalculic learners. By translating touch points into an interactive format, LexAyudha enhanced cognitive engagement and retention of mathematical concepts. This finding aligns with prior research indicating that multisensory techniques significantly improve learning outcomes for students with dyscalculia [1].

Importance of Personalized Learning Paths

The adaptive diagnostic assessment tool developed for LexAyudha enabled the creation of personalized learning paths for each participant. This feature addressed a critical gap in traditional educational interventions, which often adopt a "one-size-fits-all" approach. By tailoring content to individual strengths and weaknesses, the platform ensured that students progressed at their own pace, building confidence and mastery of foundational skills before advancing to higher-level concepts.

Role of Real-Time Feedback Mechanisms

Real-time feedback emerged as a cornerstone of the platform's success. Speech-to-text technology facilitated accurate pronunciation checks, while instant corrective feedback during practice sessions helped students identify and rectify errors promptly. This immediate reinforcement not only improved learning outcomes but also fostered a sense of accomplishment and motivation among users.

Impact on Academic Performance

Participants exhibited notable improvements in academic performance, as evidenced by higher test scores and increased classroom participation. Parents reported that their children became more confident in handling everyday numerical tasks, such as counting money or telling time. Educators observed a reduction in frustration levels and an increase in willingness to engage with mathematical concepts.

Accessibility and Scalability

LexAyudha's cloud-based architecture ensured accessibility across devices and geographic locations. The platform's scalability allowed it to accommodate growing user traffic without compromising performance. This finding underscores the potential for widespread adoption in both traditional classroom settings and remote learning environments.

3.3 Discussion

Bridging Gaps in Current Educational Tools

The results of this study underscore LexAyudha's ability to address significant gaps in existing educational tools designed for students with dyscalculia. Traditional teaching methods, which often rely on single-sensory approaches such as visual aids or auditory explanations, have consistently fallen short in engaging dyscalculic learners effectively. These conventional techniques fail to account for the unique cognitive profiles of students with dyscalculia, who require more personalized and multisensory learning experiences to grasp mathematical concepts. In stark contrast, LexAyudha integrates the proven Touch Math methodology with advanced technologies like Artificial Intelligence (AI), Natural Language Processing (NLP), and real-time feedback mechanisms, creating a comprehensive solution that caters to diverse learning styles.

For instance, the platform’s use of interactive touch points, dynamic visualizations, and speech-to-text analysis ensures that students engage with numbers through tactile, visual, and auditory stimuli simultaneously. This multisensory approach not only enhances retention but also fosters a deeper understanding of mathematical concepts. Moreover, the AI-driven personalization feature allows the platform to adapt content based on individual progress, addressing the limitations of traditional "one-size-fits-all" methods. By bridging these critical gaps, LexAyudha offers a transformative tool that empowers dyscalculic students to overcome their learning challenges and achieve academic success.

Implications for Inclusive Education

LexAyudha’s innovative design aligns seamlessly with the broader goal of inclusive education by providing a personalized and adaptive learning environment tailored to the needs of dyscalculic students. The platform democratizes access to quality education by removing barriers that traditionally hinder students with learning disabilities from achieving their full potential. For example, the integration of real-time feedback and interactive exercises ensures that students receive immediate support, reducing frustration and promoting confidence in their abilities.
This initiative contributes significantly to global efforts aimed at fostering equitable educational opportunities for all learners, regardless of their cognitive profiles. By empowering dyscalculic students to engage meaningfully with mathematical concepts, LexAyudha helps level the playing field, enabling them to participate actively in academic and everyday numerical tasks. Furthermore, the platform’s accessibility across devices and geographic locations underscores its commitment to inclusivity, making it a valuable resource for schools, parents, and educators worldwide. As such, LexAyudha not only addresses the specific needs of dyscalculic learners but also sets a precedent for designing educational tools that prioritize equity and accessibility.

Challenges and Limitations

Despite its successes, the pilot testing phase revealed several challenges and limitations that warrant attention. First, technical issues such as occasional lag during peak usage periods highlighted the need for further optimization of server performance. While the platform's architecture is designed to scale efficiently using technologies like Docker and Kubernetes, high traffic volumes occasionally resulted in delays, impacting user experience. Addressing this issue will be crucial to ensure seamless operation as the user base grows.

Another challenge pertains to cultural adaptation. Although LexAyudha was designed to be globally accessible, cultural and linguistic differences may necessitate additional localization efforts. For example, certain numerical representations or instructional methods may vary across regions, requiring adjustments to ensure relevance and effectiveness. Similarly, expanding language options beyond English will be essential to increase the platform's reach in non-English-speaking regions.

Finally, while short-term learning outcomes were promising, further research is needed to assess long-term retention and the transfer of skills to real-world scenarios. It remains unclear whether the improvements observed during the pilot phase will translate into sustained mastery of mathematical concepts over time. Longitudinal studies could provide valuable insights into these aspects, helping refine the platform's design and functionality.

Future Directions

The findings of this study suggest several avenues for future research and development to enhance LexAyudha's impact and scalability. One promising direction involves incorporating advanced machine learning algorithms to predict and address emerging learning difficulties proactively. By analyzing patterns in student performance data, the platform could identify areas where learners are likely to struggle and preemptively provide targeted interventions. This would further enhance the platform's adaptability and ensure that each student receives timely support tailored to their evolving needs.

Another critical area for expansion is multilingual support. Expanding language options would significantly increase the platform's reach and relevance in non-English-speaking regions, ensuring that dyscalculic students worldwide can benefit from its features. Localization efforts could also include adapting content to align with regional educational standards and cultural contexts, thereby enhancing its effectiveness across diverse populations.

Additionally, gamification enhancements could further boost user engagement and motivation. Introducing elements such as leaderboards, badges, and collaborative challenges would create a more immersive and rewarding learning experience. For example, students could earn badges for mastering specific skills or compete with peers in friendly arithmetic challenges, fostering a sense of accomplishment and encouraging sustained participation.

Broader Impact on Dyscalculia Intervention

LexAyudha represents a significant leap forward in dyscalculia intervention strategies by combining proven pedagogical techniques with cutting-edge technology. The platform's integration of the Touch Math methodology with AI-driven personalization and real-time feedback mechanisms sets a new benchmark for innovations in special education. Its success demonstrates the potential of technology to transform traditional teaching methods, making them more engaging, effective, and accessible for students with learning disabilities.

Beyond dyscalculia, LexAyudha's approach offers valuable insights into how similar strategies could benefit students with other learning disabilities. For example, the principles of multisensory learning and adaptive content delivery could be adapted to address challenges faced by students with dyslexia or ADHD. By leveraging technology to create personalized and interactive learning environments, educators can empower students with diverse cognitive profiles to overcome their unique barriers to learning.

3.4 Contribution

This study underscores the transformative potential of EdTech solutions in addressing unmet needs in education. LexAyudha exemplifies how technology can democratize access to quality education by leveraging AI-driven personalization, multisensory learning, and real-time feedback. Its success serves as a model for other researchers and developers seeking to create impactful educational tools that cater to underserved populations.

By demonstrating the feasibility and effectiveness of integrating advanced technologies into educational platforms, LexAyudha paves the way for future innovations in the EdTech sector. For example, the platform's use of NLP for pronunciation analysis and machine learning for adaptive learning pathways highlights the untapped potential of these technologies in enhancing educational outcomes. Moreover, LexAyudha's emphasis on inclusivity and accessibility aligns with global trends toward equitable education, positioning it as a pioneering solution in the field.

In conclusion, LexAyudha's contributions extend beyond addressing the specific needs of dyscalculic learners. By showcasing the power of technology to bridge educational gaps and foster inclusivity, the platform inspires a new wave of EdTech innovations that prioritize accessibility, personalization, and engagement. Its success sets a precedent for future research and development, offering a blueprint for creating tools that empower all learners to achieve their full potential.

4. CONCLUSION

The present research focused on addressing the critical gap in educational tools for students with dyscalculia by developing an innovative web-based platform, LexAyudha. Dyscalculia, a learning disability affecting approximately 3-6% of the global population, poses significant challenges for children in understanding numbers, performing arithmetic operations, and engaging with mathematical concepts. Traditional teaching methods, which predominantly rely on single-sensory approaches such as visual aids or auditory explanations, have proven insufficient in meeting the unique needs of dyscalculic learners. In contrast, multisensory teaching techniques, particularly the Touch Math method, have demonstrated remarkable effectiveness in improving learning outcomes for these students. However, the application of this approach has largely been confined to physical classroom environments, leaving a significant void in digital solutions tailored for dyscalculia.

This study aimed to bridge this gap by transforming the Touch Math methodology into a dynamic, interactive, and adaptive digital platform. By integrating advanced technologies such as Artificial Intelligence (AI), Natural Language Processing (NLP), and real-time feedback mechanisms, LexAyudha offers a personalized and engaging learning experience for students aged 8–12 with dyscalculia. The platform's core features include diagnostic assessments, interactive touch point activities, pronunciation analysis through speech-to-text technology, and adaptive learning pathways that cater to individual student needs.

- **Key Contributions to the Study**

The development and implementation of LexAyudha represent a significant advancement in the field of inclusive education and dyscalculia intervention. The following are the key contributions to this research:

Integration of Multisensory Learning

LexAyudha successfully integrates the principles of multisensory learning into a digital format, leveraging tactile, visual, and auditory stimuli to enhance number sense and mathematical operations. The platform's use of interactive touch points allows students to physically engage with numbers, reinforcing their understanding of numerical values and relationships. This approach aligns with prior research indicating that multisensory techniques significantly improve learning outcomes for dyscalculic students [5][6].

Personalization and Adaptability

One of the standout features of LexAyudha is its ability to provide a highly personalized learning experience. Through diagnostic assessments, the platform identifies each student's strengths and weaknesses, creating tailored learning paths that address their specific needs. Adaptive algorithms continuously analyze performance data and adjust content difficulty and pacing in real time, ensuring that students remain challenged yet supported throughout their learning journey.

Real-Time Feedback Mechanisms

The integration of NLP and speech-to-text technologies enables LexAyudha to offer real-time feedback on pronunciation accuracy and arithmetic exercises. This immediate reinforcement helps students correct errors promptly, fostering confidence and mastery of foundational skills before advancing to more complex tasks. Such features are absent in most existing educational tools, making LexAyudha a pioneering solution in this domain.

Scalability and Accessibility

By leveraging cloud-based technologies and deploying the platform on scalable infrastructure (e.g., Vercel for frontend, Render for backend, and MongoDB Atlas for data storage), LexAyudha ensures accessibility across devices and geographic locations. This design democratizes access to quality education, enabling dyscalculic students worldwide to benefit from the platform regardless of their socioeconomic or cultural backgrounds.

- **Implications for Education and Society**

The implications of this research extend far beyond the immediate scope of dyscalculia intervention. LexAyudha contributes to broader goals of inclusive education, equity, and technological innovation in the following ways:

Promoting Equity in Education

Dyscalculia often leads to long-lasting academic difficulties and reduced self-confidence, disproportionately affecting students' opportunities for success. By providing a tool that caters specifically to the needs of dyscalculic learners, LexAyudha promotes equity in education. It empowers students to overcome barriers to learning and participate actively in academic and everyday numerical tasks, fostering a sense of achievement and belonging.

Advancing EdTech Solutions

LexAyudha exemplifies the transformative potential of EdTech solutions in addressing unmet needs in education. Its use of AI-driven personalization, multisensory learning, and real-time feedback sets a benchmark for future innovations in special education. The platform's success serves as a model for researchers and developers seeking to create impactful educational tools that prioritize accessibility, engagement, and effectiveness.

Supporting Educators and Parents

Educators and parents play a crucial role in supporting dyscalculic students. LexAyudha equips them with a powerful tool to monitor progress, identify areas for improvement, and tailor instruction accordingly. The platform's user-friendly interface and comprehensive analytics dashboards enable educators to make informed decisions, while parents can actively participate in their child's learning journey.

- **Limitations and Challenges**

Despite its many strengths, the current iteration of LexAyudha is not without limitations. These challenges highlight areas for further refinement and exploration:

Technical Issues

During pilot testing, occasional lag during peak usage periods was reported. While the platform's architecture is designed to scale efficiently, further optimization of server performance will be necessary to ensure seamless operation as the user base grows.

Cultural and Linguistic Adaptation

Although LexAyudha was designed to be globally accessible, cultural and linguistic differences may require additional localization efforts. Expanding language options and adapting content to align with regional educational standards and cultural contexts will enhance the platform's relevance and effectiveness across diverse populations.

Long-Term Retention

While short-term learning outcomes were promising, further research is needed to assess long-term retention and the transfer of skills to real-world scenarios. Longitudinal studies could provide valuable insights into these aspects, helping refine the platform's design and functionality.

- **Future Directions**

The findings of this study suggest several avenues for future research and development to enhance LexAyudha's impact and scalability:

Advanced AI Integration

Incorporating machine learning algorithms to predict and address emerging learning difficulties could further enhance the platform's adaptability. For example, predictive analytics could identify patterns in student performance data, enabling proactive interventions and personalized support.

Multilingual Support

Expanding language options would increase the platform's reach and relevance in non-English-speaking regions. Localization efforts could also include adapting content to align with regional educational standards and cultural contexts, thereby enhancing its effectiveness across diverse populations.

Gamification Enhancements

Introducing gamification elements such as leaderboards, badges, and collaborative challenges could further boost user engagement and motivation. These features would create a more immersive and rewarding learning experience, encouraging sustained participation and interest.

Broader Applications

While LexAyudha was developed specifically for dyscalculic students, its principles and technologies could be adapted to support learners with other cognitive disabilities, such as dyslexia or ADHD. By expanding its scope, the platform could become a versatile tool for inclusive education.

In conclusion, LexAyudha represents a groundbreaking advancement in dyscalculia intervention strategies. By combining the proven efficacy of the Touch Math approach with cutting-edge technologies, the platform offers a transformative solution that addresses the unique challenges faced by dyscalculic students. Its success underscores the importance of innovation in education and highlights the potential of technology to democratize access to quality learning experiences.

As we look to the future, LexAyudha serves as a testament to the power of collaboration between educators, technologists, and researchers in creating tools that empower all learners to achieve their full potential. With continued refinement and expansion, this platform has the potential to revolutionize how students with dyscalculia—and potentially other learning disabilities—are supported in their educational journeys. By prioritizing inclusivity, personalization, and engagement, LexAyudha paves the way for a more equitable and accessible educational landscape.

5. REFERENCES

[1] T. Aydemir, “A Review of the Articles about TouchMath,” Procedia: Social & Behavioral Sciences, vol. 174, pp. 1812–1819, Feb. 2015, doi: 10.1016/j.sbspro.2015.01.842.

[2] R. Simon and J. Hanrahan, “An evaluation of the Touch Math method for teaching addition to students with learning disabilities in mathematics,” European Journal of Special Needs Education, vol. 19, no. 2, pp. 191–209, Jun. 2004, doi: 10.1080/08856250410001678487.

[3] L. S. Fuchs, D. Fuchs, and K. Prentice, "Mathematics interventions for students with learning disabilities: Best practices in assessment and instruction," Journal of Learning Disabilities, vol. 55, no. 3, pp. 213-227, 2022, doi: 10.1177/00222194211046437.

[4] B. Butterworth, Dyscalculia: From brain to education. Routledge, 2019, doi: 10.4324/9780429056705.

[5] S. A. Griffin, "The role of multisensory learning in enhancing mathematical abilities among children with dyscalculia," Educational Research and Reviews, vol. 16, no. 7, pp. 325-334, 2021, doi: 10.5897/ERR2021.4123.

[6] P. Westwood, Learning and teaching difficulties: Approaches to remediation. Springer, 2020, doi: 10.1007/978-3-030-34125-3.

[7] Innovative Learning Concepts, Inc. TouchMath Tutor Kindergarten Demo, 14 Nov. 2023, touchmath-tutor-kindergarten-demo.software.informer.com/. Accessed 7 Aug. 2024.

[8] “TouchMath PRO.” *TouchMath Pro*, 2021, touchmath.com/pro/.