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An Adaptive E-learning Platform for Primary School Children with Visual Impairment

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***Abstract* - Condition wherein an individual experiences a complete or partial loss of vision. It stands as one of the most prevalent disabilities worldwide. Frequently, a comprehensive remedy for this condition remains elusive. Consequently, individuals living with blindness learn to integrate it as a part of their lives. With the intention of assisting those with visual impairments, this research focuses on creating a mobile application encompassing four key features: a module for recommending tutors, a voice-operated calculator, an interactive gaming component, and a supportive voice assistant. The main objective of our application is to enhance the online learning experience for visually impaired elementary school children. A survey of visually impaired primary students demonstrated the system's accuracy, feasibility, effectiveness, and engagement. The results confirm the system's positive impact on the education of visually impaired students, offering a promising path towards inclusive and empowering learning environments.**

Keywords: E-learning, Accessibility, Visually Impaired Education, Primary students, Learning Environment.

I. INTRODUCTION

Due to an increasing emphasis on inclusivity and equal opportunity for all learners, the education of visually impaired pupils has received substantial attention in recent years. Visual impairment encompasses a wide range of diagnosis, such as partial or total blindness, limited vision, and a variety of eye disorders. These students confront distinct problems in gaining access to school, participating in classroom activities, and developing the skills required for personal and academic development.

Understanding the historical background of visually impaired education helps to highlight both the achievements and the challenges that remain. Visually handicapped pupils have historically been marginalized, ostracized, or restricted to specialized schools. The landscape has transformed, however, with the growth of disability rights groups and inclusive education ideals, leading to more inclusive and accessible educational environments.

Inclusive education is critical for empowering visually impaired pupils. It entails giving them equitable access to mainstream educational environments, making appropriate accommodations, and providing specific support services. This section addresses the advantages of inclusive education, such as social integration, increased self-esteem, and improved academic results.

Visually challenged students face a variety of challenges in their educational path. Limited access to educational materials, inaccessible learning environments, a lack of specialized equipment, social stigma, and attitudinal impediments, these obstacles. These affect the academic and personal development of visually impaired students.

The educational experiences of visually impaired pupils have been transformed by technological breakthroughs in the past. There are numerous assistive technologies such as screen readers, Braille displays, tactile graphics, and digital resources, include the issues with current technological solutions in brief.

II. LITERATURE REVIEW

The rapid advancement of technology has ushered in new opportunities in education, particularly within e-learning platforms. Ensuring that these platforms are comprehensive and accessible to all learners, including those with visual disabilities, is imperative. Visually impaired students require unique methods to enhance their educational experiences.

Numerous researchers have dedicated their efforts to understanding the needs of visually impaired students in the context of digital platforms for online learning. Current studies have investigated how these students engage with digital platforms, the challenges they face, and the types of digital platforms best suited to their needs [1].

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To enhance the online classroom experience for visually impaired students, several approaches have emerged. One approach involves the integration of learning technology with pedagogy, students, facilitators, and the creation of an inclusive learning environment [2]. Another framework focuses on the integration of innovative learning techniques with instruction, students, facilitators, and the establishment of a comprehensive learning environment [3].

This review aims to examine current research on e-learning programs specifically designed for visually impaired pupils. We seek insights into the design elements and features that can enhance the usability and efficiency of such platforms. Four main topics are the focus of our exploration: Supportive voice bots, simple voice-based calculators, voice-based gaming modules, and tutor recommendation modules based on knowledge levels and disabilities.

Advancements in technology have played a pivotal role in creating inclusive learning environments. IBM's pioneering work in digital voice recognition technology in the 1990s marked the initial step towards transformative innovations. Subsequently, Apple's Siri, Google's "Google Now," Microsoft's "Cortana," and Amazon's "Amazon Alexa" have led to the era of voice-driven experiences [4].

Recent research [5] has demonstrated the capability to translate speech into various accents, such as Japanese. This sophisticated text-to-speech model uses the power of BERT to ensure accurate pronunciation and even adapts the tone based on the emotions expressed in the input text. Such advancements mark significant achievements in text-to-speech technology [6].

Daily tools like calculators have also seen improvements. Smartphone calculator apps now offer voice commands, making calculations accessible to those who are unable to see or use traditional calculators. Innovations like the Voice Input Speech Output (VISO) Calculator's Bangla Speech Recognition have been implemented to address this need [7].

Educational tools tailored to visually impaired individuals have garnered attention. The Edu Braille calculator, introduced in 2019, can display Braille codes, although it lacks sound features. Further enhancements are needed to make it more effective, such as sound cues and additional displays on Android smartphones [8]. Additionally, a voice calculator with Braille capabilities has been developed, albeit with room for self-correction improvements [9].

Studies like "Design and implementation of an educational game considering issues for visually impaired people inclusion" [10] and “Design, implementation, and evaluation of a mobile game for blind people: toward making mobile fun accessible to everyone” [11] have focused on creating engaging educational games with audio-based components. Meanwhile, "Egg Pair–A Hearing Game for the Visually Impaired People Using RFID” [12] explores RFID-based games.

Innovations extend to online examinations, with "Voice-based Online Examination System for Visually Impaired Students" proposing a voice-command-driven assessment approach [13]. Another system under "Online Examination System for Visually Challenged" has been designed to provide a more accessible testing method for visually impaired pupils, incorporating voice commands and speech-to-text conversion [14].

An Android app named “FindMyTutor: A Private Tutor Matching Service” has been developed, where students can select tutors based on their grades in online tests. This approach aligns with our categorization of visually impaired pupils according to their grade level and disability [15].

While these studies provide valuable insights, synthesizing these technologies is crucial. A longitudinal study should be conducted, focusing on the integration of access technologies, e-learning facilitation tools, and assessment mechanisms. This study will evaluate the sustained impact of these technologies on the educational journey of visually impaired students over time.

III. METHODOLOGY

The main objective of our application is to enhance the online learning experience for visually impaired elementary school children. This comprehensive solution consists of several interconnected sub-objectives.

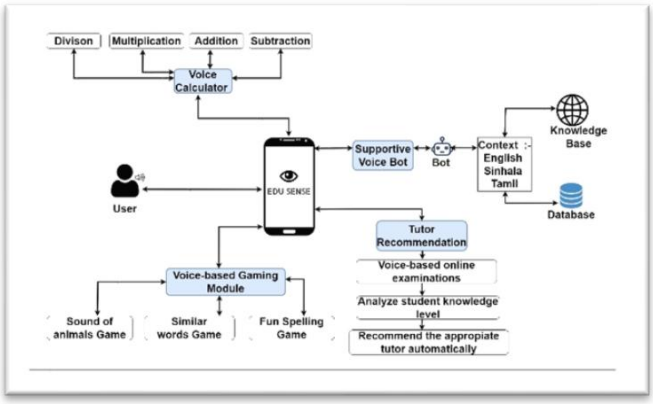

Figure 1: Overall System Diagram

Figure 1 represents the Overall System Diagram of the Edu Sense e-learning platform. This diagram illustrates the system's four main functions: a Supportive voice bot in multilingual languages, a Voice-Based Calculator module that

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seamlessly integrates mathematical functions a Gaming module with three voice-based games and a Tutor recommendation system. The system first administers voice-based online exams to test student knowledge levels before recommending relevant tutors based on the results.

Supportive voice bot

The technique and execution points of interest of developing a multilingual voice bot able of understanding and reacting to client input in three languages: English, Sinhala, and Tamil are presented in this research paper. To form a seamless conversational involvement with clients, the voice bot leverages natural language processing (NLP) procedures such as text-to-speech (TTS), speech-to-text (STT), tokenization, lemmatization, and Wikipedia search. Users can engage with the proposed voice bot by utilizing voice commands in any of the supported languages, allowing for greater accessibility and usability across varied linguistic populations.

Several critical phases are involved in constructing a multilingual speech bot to ensure its operation and efficacy across multiple languages. The procedure starts with data collection and preprocessing. To train the language detection methods, datasets in English, Sinhala, and Tamil must be obtained. The gathered data is subsequently preprocessed, which entails the elimination of noise, special characters, and extraneous information, preparing the data for later phases. Language detection methods are implemented in Step 2. This entails determining the language of user input using libraries such as 'Langdetect' or other appropriate ways. The recognized language is saved in the processing pipeline for future reference. Step 3 focuses on the development of Language-Specific Functions and Responses. These demands customizing the welcome messages and answers to each supported language. Additionally, unique text-to-speech (TTS) and play audio routines are generated for each language utilizing appropriate TTS libraries. Step 4 addresses tokenization and lemmatization. Each language has its own tokenization and lemmatization functions: English, Sinhala, and Tamil. To effectively preprocess the text, language-specific tokenization, and lemmatization libraries, as well as custom rules, are used. In step 5, a Language-Specific Wikipedia Search feature is added. The generate Response function has been modified to perform language-specific Wikipedia searches based on the language recognized before. Language-specific Wikipedia search libraries or APIs are used to retrieve relevant information from Wikipedia for each language. The procedure concludes with Integration and Testing (step 6). All the language-specific features created thus far have been smoothly merged into the main voice bot code. Extensive testing follows, encompassing a wide range of user inputs in several languages. This extensive testing step is critical in verifying the voice bot's durability, accuracy, and general efficacy across multiple languages.

A) Voice Based Calculator

"EduSense," an inclusive and empowering application, is tailored to meet the unique needs of visually impaired students, fostering an environment of accessible and effective learning. At the core of EduSense lies the transformative "Voice-Based Calculator" module, seamlessly integrated to provide an exceptional tool for mathematical calculations. This innovative module enables users to effortlessly perform calculations using voice input or touch interactions, ensuring a user-centric experience. Developed as an integral component of EduSense, the "Voice-Based Calculator" module is a testament to modern technology's potential to enhance accessibility and inclusivity within education.

The "Voice-Based Calculator" module within EduSense extends its capabilities by offering dual modes of interaction: voice and touch. Leveraging the power of the @react-native-voice/voice library, voice inputs are accurately interpreted to execute mathematical operations. By harmonizing a React Native frontend with a Python backend, the module achieves a seamless synergy between technology and user experience. The Python backend, supported by the speech recognition library, captures voice input and employs the eval function to evaluate mathematical expressions. The module not only delivers results through voice outputs but also stores accurate responses in a dedicated database, reaffirming its commitment to functionality and utility. Edu Sense's "Voice-Based Calculator" module exemplifies innovation driven by accessibility, providing visually impaired students with a transformative tool for mathematical exploration and learning.

B) Gaming module

The Edu Sense application's gaming module is designed for visually impaired users. The module consists of three voice-based games: the Animal Sound Game, the Fun Spelling Game, and the Synonyms Game. The methodology envelops the creation of the games, the information collection prepares, and the assessment of client performance.

The games were created using a combination of programming languages and technologies, including speech recognition computer program, sound handling libraries, and client interface design frameworks. The design of each game involved crafting a user-friendly interface and integrating voice interaction components.

Animal Sound Game: Animal sounds were sourced from reputable audio databases and integrated into the game's

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framework. The game was programmed to randomly select an animal sound and play it through the device's speaker. Voice recognition software was implemented to capture the user's response, compare it to the correct answer, and provide appropriate feedback.

Fun Spelling Game: A word database was curated for the game, encompassing a diverse range of vocabulary suitable for visually impaired users. The game system was designed to retrieve and play a word through the speaker. Users were prompted to spell the word aloud, and their response was converted to text using speech-to-text technology. The system then compared the user's spelling to the correct spelling, offering feedback accordingly.

Synonyms Game: A database of synonyms was compiled that included the most common words in the language context of the target user. The game presented users with a word played through the speaker. Users were prompted to provide a synonym word using their voice, and the response was converted to text. The system compared the user's synonym word with the correct synonym and provided feedback.

We went ahead and included accessibility features like increasing and decreasing letter sizes, high contrast adjustments, and altering spacing between letters right on the main page. This way, users can easily customize the content to suit their preferences.

C) Tutor recommendation

The methodology for the recommended e-learning system for visually impaired primary school kids is structured around a cohesive process designed to provide tailored educational resources and specialized online tutoring. The system leverages MongoDB for efficient database management and utilizes React Native for the development of a user-friendly mobile application and a desktop application for administrative tasks. The process begins by obtaining grade-level specific questions from the MongoDB database. The system will conduct an online voice-based examination, featuring a collection of multiple-choice questions for this.

The process commences with the administration module, accessible through the desktop application that has been developed by using React. This module provides authorized administrators with the capability to create new questions, edit existing ones, delete questions, and perform targeted searches by question name. The desktop application's intuitive interface guarantees efficient management and upkeep of the question bank, thus ensuring the relevance and accuracy of the educational content.

These questions are then made accessible to the learners through the React Native app, where voice commands are used to navigate and respond to the online examination. The system's front-end converts the students' spoken answers into text format, which is subsequently stored in the database for analysis.

Upon completion of the online exam, the server retrieves and processes the exam information from the database. This includes evaluating the student's overall performance, time taken, and determination of their knowledge level. The system utilizes a dataset containing information about students' grades, subjects, exam scores, time allocation per question, and knowledge levels, which is then processed using a rule-based classifier to assess the students' level of understanding. Based on this assessment, the system recommends the most suitable tutor from a pool of available tutors.

The recommended tutor is then notified with relevant student information, and if the tutor agrees to the assignment, tutoring sessions can commence. The React Native application is employed once again, this time facilitating communication between the student and tutor through voice commands. This streamlined approach ensures that visually impaired students receive not only tailored educational resources but also specialized tutoring, fostering their academic growth and expanding their opportunities.

We've incorporated accessibility features on each page, including options to enlarge or shrink letter sizes, apply high contrast mode, and adjust spacing between letters. This empowers the visually impaired students to customize the content based on their preferences.

Similarly, we have achieved the main objective of our application, enhancing the online learning experience for visually impaired primary school students. As our first sub-objective, we were able to develop a supportive voice bot that operates in multiple languages. Additionally, we had an aim to create an e-learning platform that integrates a user-friendly voice-based calculator for simplified calculations. We have successfully achieved this goal. Our platform also concentrated on engaging learners through educational games, fostering an interest in studies, and incorporating accessibility features to enhance vision. We have succeeded in this sub-objective as well. Finally, we successfully achieved the last sub-objective by providing tailored tutor recommendations based on learners' knowledge levels and disabilities.

Overall, the methodology encompasses a well-defined sequence of steps to offer an inclusive and effective e-learning experience for visually impaired primary school students.

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IV. RESULTS AND DISCUSSION

We conducted a physical survey at Ratmalana School for the Blind, involving 10 primary students, to measure the feasibility, effectiveness, and student engagement with visually impaired students.

We examined the feasibility of our e-learning system in this part to clarify its usefulness and appropriateness for elementary school children who are visually impaired. In our investigation, the following queries and standards were considered.

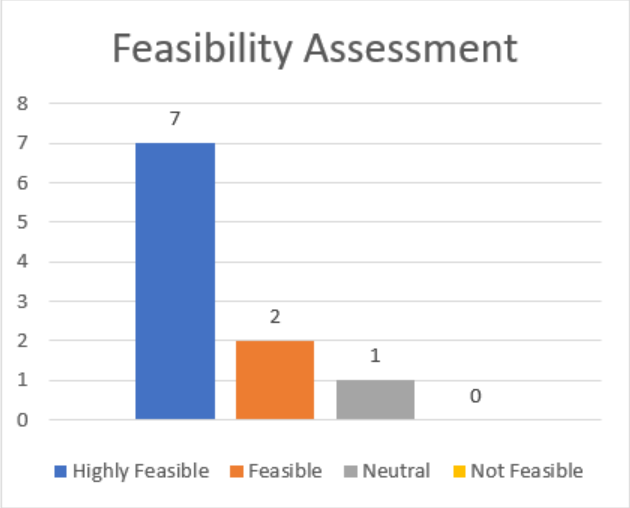

Figure 2: Feasibility of the developed e-learning system for visually impaired students in addressing their unique educational needs

Most of the students (70%) found the e-learning application (Edu Sense) to be highly feasible, while 20% considered it as feasible. Only 10% of the students assumed a neutral stage, and none of the students responded as not feasible.

A critical analysis was conducted on the feasibility of the accessibility modes in the UI design of the e-learning system. Ensuring the user interface addressed to the needs of children with visual impairments was crucial. We explored how well the design met their specific needs and made sure they could still access it.

The survey's results provided important information by revealing the general feasibility of these novel components.

In this part, we examined the effectiveness of our e-learning system and how effectively it can address the unique needs and educational requirements of visually impaired elementary children.

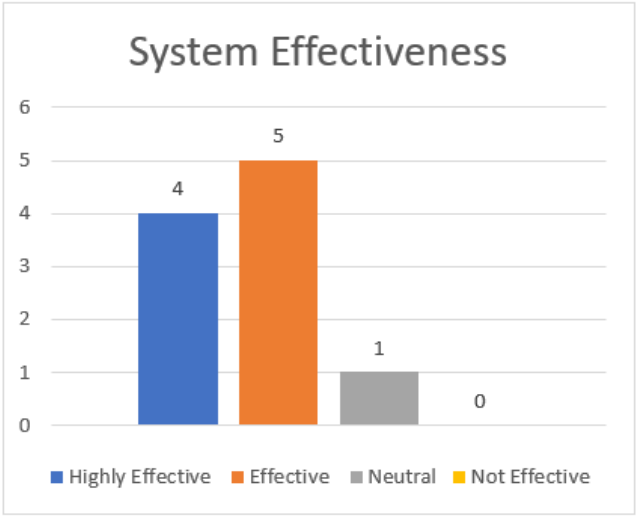

Figure 3: To what extent do you believe the e-learning system effectively addresses the educational requirements of visually impaired students while considering their specific challenges?

Most of the students (50%) found the e-learning application (Edu Sense) to be Effective, while 40% considered it as Highly Effective. A neutral stage was assumed by only 10% of the students, and none of them responded as not being effective.

We examined how the Voice-Based Tutor Recommendation Module added to the overall effectiveness of the e-learning program. We aimed to determine its efficacy in carrying out its intended use by assessing its influence on the students' learning experiences.

The Speech-Based Gaming Module is essential to the e-learning system's effectiveness. It was anticipated that the module will have a good influence on the system's overall efficacy by encouraging participation and interactive learning experiences.

Our research focused on how well voice-based calculator features enhanced the educational experience, as it was designed to offer an easily navigable tool for mathematical computations.

We examined how the voice bot affected the e-learning system's overall efficacy, accessibility, and inclusion as it supported three languages.

This section focused on the level of engagement that visually impaired primary pupils encountered while utilizing our e-learning platform.

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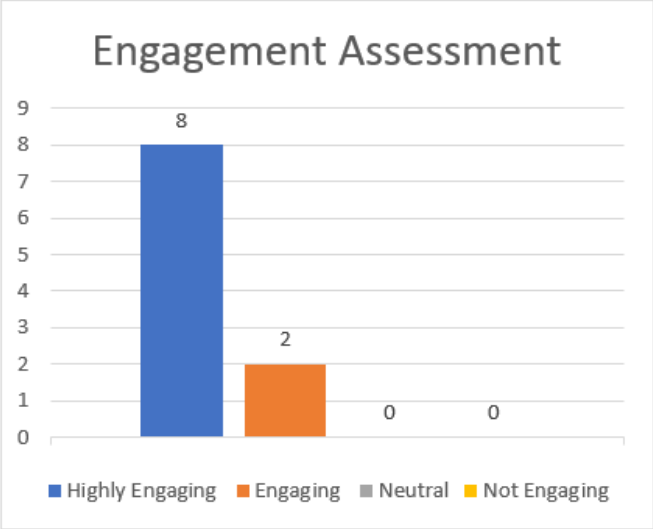

Figure 4: How effectively does the e-learning system engage visually impaired students in their learning journey?

Most of the students (80%) found the e-learning application (Edu Sense) to be highly Engaging, while 20% considered it as Engaging. None of the students responded as Neutral or not Engaging.

We evaluated how the gaming module affected the level of student participation. We wanted to see how these games affected students' overall involvement and how much of an influence they had.

Students' involvement is greatly encouraged by the Tutor Recommendation Module, which is based on the results of an online exam and their impairment. We investigated the effects on student involvement and the educational process of personalized tutor suggestions and monitoring tutoring sessions.

The availability of the Voice-Based Simple Calculator was an additional significant feature that could impact user participation.

Additionally, our investigation focused on how the multilingual Supportive Voice Bot improved students' overall e-learning system engagement. This feature greatly increased student engagement by offering a smooth and welcoming environment.

We considered the comments and answers received from the survey, which emphasized the influence of voice input and response capabilities on student involvement.

Table 1: Features comparison; R1: Proposed system; R2: Research 1[6]. R3: Research 2[7]; R4: Research 3[11]; R5: Research 3[15]

Features	R1	R2	R3	R4	R5
Speech-based tutor suggestion module	✓	×	×	×	×
Speech-based gaming module	✓	×	×	×	×
Accessibility modes in UI design	✓	✓	✓	×	✓
Voice input and response capabilities	✓	✓	✓	✓	✓
Supportive voice bot for multilingual languages	✓	×	×	×	×
Voice-based calculator	✓	×	×	×	×

Our e-learning system introduces a Speech-Based Tutor Suggestion Module, a feature that is not present in R2 [6], R3[7], R4 [11], or R5[15]. Our system incorporates a Speech-Based Gaming Module, which is not found in R2 [6], R3[7], R4 [11], or R5[15]. While R2[6], R3[7], and R5[15] include accessibility modes in their UI design, our system takes this a step further by incorporating a more comprehensive set of accessibility features. The presence of voice input and response capabilities is a common feature across all research, including ours. This signifies a shared commitment to leveraging voice technology to facilitate interaction and engagement among visually impaired students. The Supportive Voice Bot is exclusive to our e-learning system.

It stands out as a distinctive element that is not available in R2 [6], R3[7], R4 [11], or R5[15]. The Voice-Based Calculator, exclusively available in our system and is not found in R2 [6], R3[7], R4 [11], or R5[15]. Serves as a valuable tool for mathematical calculations. In summary, the comparative analysis of features highlights the unique contributions of our e-learning system to the field of accessible education for visually impaired primary students.

By incorporating the available features such as a speech based tutor suggestion module, a speech-based gaming module, accessibility modes in UI design, voice input and response capabilities, a supportive voice bot for multilingual languages, and a voice-based calculator, we can ensure that the proposed research stands out as more effective compared to another existing research.

We are confident that our e-learning application has achieved success and effectively fulfilled the main objectives of this research based on the insights gathered from this survey.

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The findings from the study are thoroughly analyzed and explained in this part. It investigates the significance of the findings regarding the study's goals and offers insights into the efficiency and usefulness of the created e-learning system for primary students with visual impairments.

The results emphasize the value of specialized e-learning programs for students who are blind or visually impaired. With equal opportunities for visually impaired students, according to the platform's positive effects on engagement and independent learning, inclusive education is significantly impacted. As a summary of findings, the study showed that the e-learning platform produced positive results, with visually challenged students expressing satisfaction and participation. The process of education was improved by the addition of a supportive voice bot, voice-based calculator, game modules and the recommendation of tutors based on knowledge and disability level.

The success of the platform to promote independent learning and create a sense of empowerment aligns with the study's goals. An inclusive learning environment was achieved through voice-based interactions and adaptive features that responded to the special needs of visually impaired pupils.

A relatively small sample size and the study's concentration on a particular age group (6 to 10 years) have limited its ability to be applied. Self-reported data may involve response bias, requiring attention to how the results are interpreted.

Future studies should examine a larger, more varied sample, considering different age groups and educational levels. And the premier features should be added to the application. We develop iOS applications as well.

The proposed e-learning platform could satisfy the needs of elementary school children who are blind or visually impaired. Further research and ongoing development are required to increase its efficiency and accessibility given its positive effects on engagement, independence, and inclusive education.

V. CONCLUSIONS

The research endeavor at hand is geared towards revolutionizing the online learning experience for visually impaired elementary school children. The overarching objective of this comprehensive solution is to enhance their access, engagement, and overall effectiveness in the realm of education. This multifaceted approach encompasses the development of a supportive voice bot, a user-friendly voice-based calculator, an engaging gaming module, and a tutor recommendation system. The primary research contribution lies in the thoughtful execution and integration of these components to address specific challenges faced by visually impaired learners.

The creation of the supportive voice bot takes center stage, catering to a multilingual audience by leveraging natural language processing techniques. This empowers learners to engage in seamless interactions across languages, ensuring an inclusive learning environment. The innovative voice-based calculator module further enriches the application, providing an intuitive tool for mathematical calculations through voice input or touch interactions. This integration signifies the application's commitment to accessibility and its potential to significantly ease the learning journey for visually impaired students. The gaming module introduces an interactive dimension to the learning process, with three distinct voice-based games designed to entertain, educate, and engage users. By sourcing animal sounds, curating word databases, and integrating voice recognition, the games not only foster interest in studies but also provide informative feedback, promoting a holistic learning experience. The methodology further introduces a tutor recommendation system, which leverages technology to match visually impaired learners with suitable tutors based on their knowledge levels and disabilities. This component aims to provide personalized support, promoting an inclusive and supportive learning atmosphere.

The application's overall contribution rests in its successful synthesis of cutting-edge technologies, including natural language processing, speech recognition, and user-friendly interfaces, to create an ecosystem that caters to the unique needs of visually impaired students. The thoughtful integration of these components addresses the outlined sub-objectives, creating an application that aims to transform the way visually impaired learners engage with educational content, enhance their skills, and foster an enduring interest in studies.

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