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Develop Equation Converter Software for Blind and Visually Impaired Students in Nigeria

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Abstract: Blind and visually impaired (BVI) students in Nigeria face significant barriers in accessing mathematics and science education due to the visual nature of equations, symbols, and scientific notations. Existing assistive tools, such as Braille and tactile graphics, often fail to adequately convey complex mathematical structures, limiting inclusion in STEM learning. This study presents the design and development of an equation converter software that transforms mathematical equations from Word documents into ASCII formats compatible with screen readers and Braille displays. Developed using C# within the .NET Framework, the system incorporates an equation parser, a custom text replacement engine, and a Unicode-to-ASCII converter to replace mathematical symbols with accessible text equivalents. The software addresses infrastructural challenges in Nigerian schools while promoting independence and equitable participation for BVI students, by enabling real-time, offline conversion. The findings highlight the potential of low-cost, context-specific assistive technologies to bridge the STEM accessibility gap, with implications for inclusive education policy and the scaling of locally relevant solutions.

Keywords: *Visual Impairment, STEM Education, Equation Converter, Assistive Technology, Inclusive Education, ASCII Conversion, Nigeria.*

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I. INTRODUCTION

In Nigeria, students with visual impairments face significant barriers to accessing mathematics and science education. This is particularly evident in secondary schools, where visually impaired students struggle to fully engage with and understand mathematical equations, scientific concepts, and other complex curriculum components. According to the World Health Organization (2021), approximately 2.4 million Nigerians live with some form of visual impairment, making it imperative to develop accessible educational resources tailored to their needs.

In Nigeria, Mathematics and Basic Science teachers commonly employ visual representations, such as equations, graphs, and charts, as instructional tools in the classroom. While these methods are effective for sighted learners, they present significant barriers for blind and visually impaired (BVI) students. The reliance on visual content without appropriate accommodations hinders the active participation and comprehension of BVI learners in these subjects. Although some schools for the blind in Nigeria utilize assistive tools like Braille, these resources remain limited in both availability and functionality. Moreover, the lack of comprehensive assistive technologies in mainstream classroom settings further widens the educational access gap for BVI students (Iyamuremye & Nsabayezu, 2023). Research by Elshaer et al. (2025) emphasises that the inaccessibility of STEM materials for visually impaired students in African countries remains a significant barrier to equitable education.

Assistive technologies, such as equation converter software offer promising solutions for enhancing the accessibility of mathematical and scientific content for blind and visually impaired (BVI) students. These tools are capable of transforming mathematical symbols and scientific equations into formats compatible with screen readers, Braille displays, or auditory outputs, thereby enabling BVI students to engage with the material more independently and effectively (Adelakun et al., 2025). Despite the existence of such technologies, their adoption remains limited in Nigeria, where issues of affordability, infrastructure, and technical support often render them inaccessible or inefficient for widespread use (Kamaghe, 2021).

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The development of specialized equation converter software designed to facilitate access to mathematics and science education for blind and visually impaired students is critical for achieving inclusive education. This study seeks to develop equation converter software for blind and visually impaired students in Nigeria.

II. LITERATURE REVIEW

The education of blind and visually impaired (BVI) students in mathematics and science subjects remains a significant challenge globally, particularly in developing countries like Nigeria. Despite advancements in assistive technologies, the gap in access to STEM education for BVI students persists, limiting their participation and success in mathematics and science learning. In Nigeria, where the population of visually impaired students is substantial, the educational system lacks inclusive tools that allow BVI students to access and engage effectively with the mathematics and science curricula (Ukah, 2022).

Braille and audio-based tools have been used to provide access to educational content for visually impaired learners in Nigeria. However, Braille has limitations, especially in conveying complex mathematical equations and scientific formulas, which require a more dynamic and comprehensive solution (Adelakun et al., 2025). In the field of assistive technologies, there are specialized software for mathematical accessibility. For instance, tools like MathType and Microsoft Mathematics offer basic functionalities for translating equations into formats suitable for screen readers. However, these tools are often not customised for the specific needs of BVI students, particularly in the context of Nigerian secondary schools. Navas-Bonilla, et al. (2025) highlight the critical role of assistive technologies in promoting inclusive education, but also emphasize that such tools must be affordable and locally adapted to be effective in resource-limited environments. This gap presents an opportunity for developing equation converter software that is both cost-effective and specifically designed for the Nigerian context, incorporating local languages, cultural relevance, and ease of use for visually impaired students (Iyamuremye & Nsabayezu, 2023).

Furthermore, the integration of audio feedback in educational software for BVI students has been shown to significantly enhance their learning experience. Studies such as Elshaer et al. (2025) demonstrate that audio-based tools that read aloud mathematical operations and provide real-time feedback are effective in helping visually impaired students perform calculations and understand complex scientific concepts. These findings suggest that developing an equation converter that can provide audio-based descriptions of mathematical formulas would be a key step in improving the accessibility of mathematics and science education for Nigerian BVI students.

However, challenges remain in implementing such systems in under-resourced educational settings. Research by Adelakun et al. (2025) indicates that the lack of infrastructure, such as computers, reliable electricity, and Internet access, limits the feasibility of deploying high-tech solutions in many Nigerian schools. Therefore, any solution must be low-cost and adaptable to offline environments while ensuring that BVI students can independently access and interact with educational content. Equation converter software is designed to convert mathematical equations and scientific formulas into formats that are accessible through screen readers, Braille, or audio-based feedback systems (Kamaghe, 2021). Such tools could enable BVI students to engage with mathematical operations, equations, and graphs in real-time, thus fostering greater independence and self-confidence in learning mathematics and science. The development of an equation converter software for mathematics and science is essential to closing this gap. This software must be designed to handle the unique needs of BVI students in Nigeria by translating mathematical equations into accessible formats, whether via screen readers, Braille, or audio outputs.

➢ *Research Objectives*

The objective of the research is to develop an equation converter software that converts mathematical equations and scientific formulas into accessible formats for BVI students.

➢ *Research Questions*

The research will address the question; how can an equation converter software be developed to effectively convert mathematical equations and scientific formulas into formats accessible to blind and visually impaired students?

III. RESEARCH METHODOLOGY

This study employed the Design Science Research (DSR) approach, a problem-solving methodology rooted in engineering and the applied sciences. DSR focuses on the creation and assessment of innovative artefacts designed to address clearly defined organizational challenges. In this research, the goal is to develop an equation converter for visually impaired persons in Nigeria. The study adopts the Design Science Research Methodology (DSRM) as proposed by Peffers et al., which outlines a six-step, iterative process: identifying and motivating the problem, establishing the objectives of a solution, designing and developing the artefact, demonstrating its use, evaluating its effectiveness, and communicating the results.

➢ *System Architecture*

The Equation to ASCII Converter is a desktop application designed to convert mathematical equations from a Word document format into ASCII representation. The application follows a client-side desktop architecture built with the following layers:

- Presentation Layer: It uses Windows Forms (UI) for user interaction.
- Business Logic: C# is used for processing the equations and handling the core functionality.
- Data Layer: The file system is used for input/output management.

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➢ *Software Development*

The software was developed using C# within the .NET Framework. The user interface was built using the Windows Forms framework. For processing Word documents, the project utilized Microsoft. Office. Interop. Word, while System.IO handled file input and output operations. String manipulation and encoding were managed using System. Text. Development was carried out in Visual Studio, with Git employed for version control and project management.

➢ *Mathematical Equation Processing*

The software features an equation parser, a custom text replacement engine that uses a predefined dictionary to convert mathematical equations into ASCII format, ensuring compatibility with screen readers and Braille displays. It comprises the following components:

- Document Loader: It processes Word files (*.docx or *.doc) using Microsoft. Office. Interop. Word.
- Unicode-to-ASCII Converter: It converts special Unicode characters (such as mathematical symbols) into their ASCII equivalents.
- Progress Tracking System: It tracks the conversion progress using a real-time update system.

➢ *Operations of the Equation Converter*

- Loading a Word Document: The user selects a Word file (.doc or .docx) using the "Choose File" button. The system validates the file extension and then extracts the document's text using Microsoft. Office. Interop. Word. An error is shown if Word isn't installed.
- Converting Equations to ASCII: After loading the document, the application processes the text and applies dictionary-based replacements (e.g., replacing the summation symbol ∑ with the word "sum"). A progress bar updates as the conversion occurs.
- Saving the Output: Once the conversion is complete, the user can select a location to save the output as a text file (.txt or .ascii).
- Resetting the Application: The user can clear all inputs and outputs, effectively resetting the application.

➢ *Class Diagram*

The class diagram illustrates the system's object-oriented design, showing the main classes, their responsibilities, and interactions. The key classes include:

- Equation Converter – The central controller of the application. It coordinates the overall process of loading a Word document, converting equations to ASCII format, saving the output, and resetting the application. The key methos include:

✓ Load Document(file: File): void – it loads the Word file into the system.
✓ Convert To Ascii(): void – It converts all equations in the loaded file to ASCII format.
✓ Save Output(location: String): void – it saves the converted output to a specified location.
✓ Reset Application(): void – it resets the software to its initial state.

- Document Loader – It handles file reading and verification of Microsoft Word installation.
- Unicode To Ascii Converter –It processes Unicode mathematical symbols and converts them into ASCII equivalents using a predefined dictionary.
- Progress Tracking System – It updates and displays the progress of the conversion in real-time.

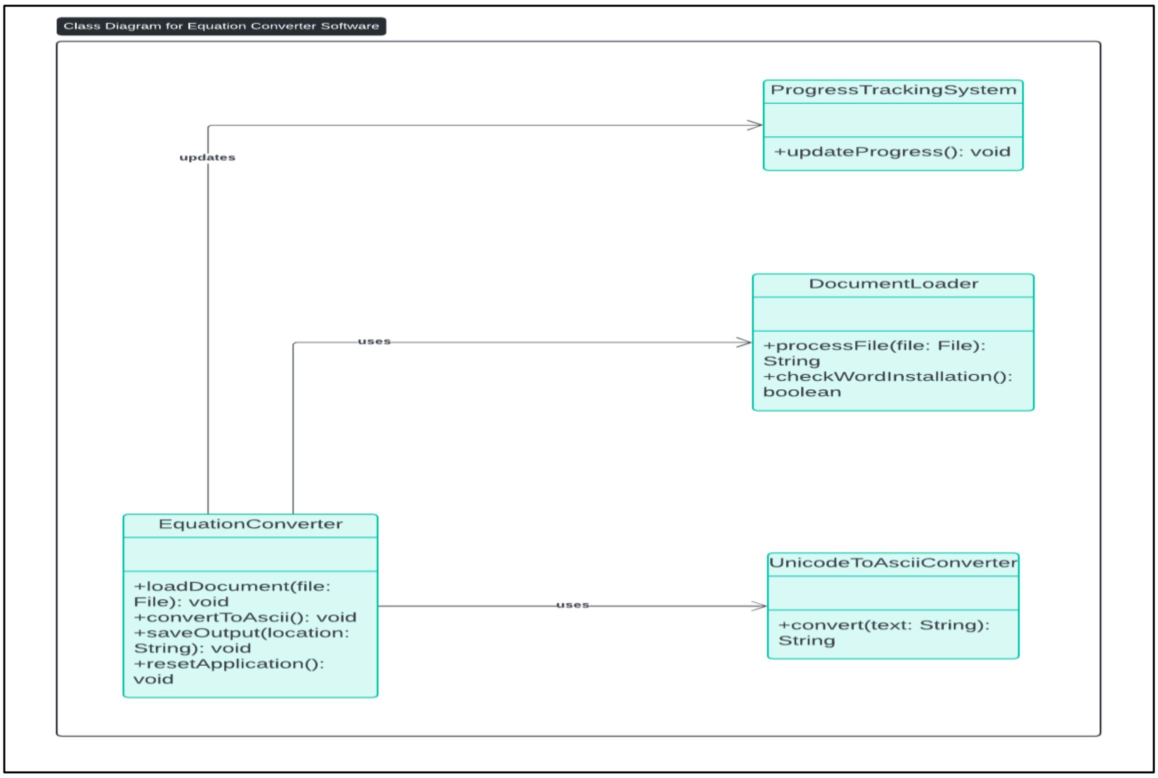

Fig 1: Class Diagram

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- *Flowchart of the Equation Converter*

The flowchart shows the logical sequence of operations in the Equation Converter Software.

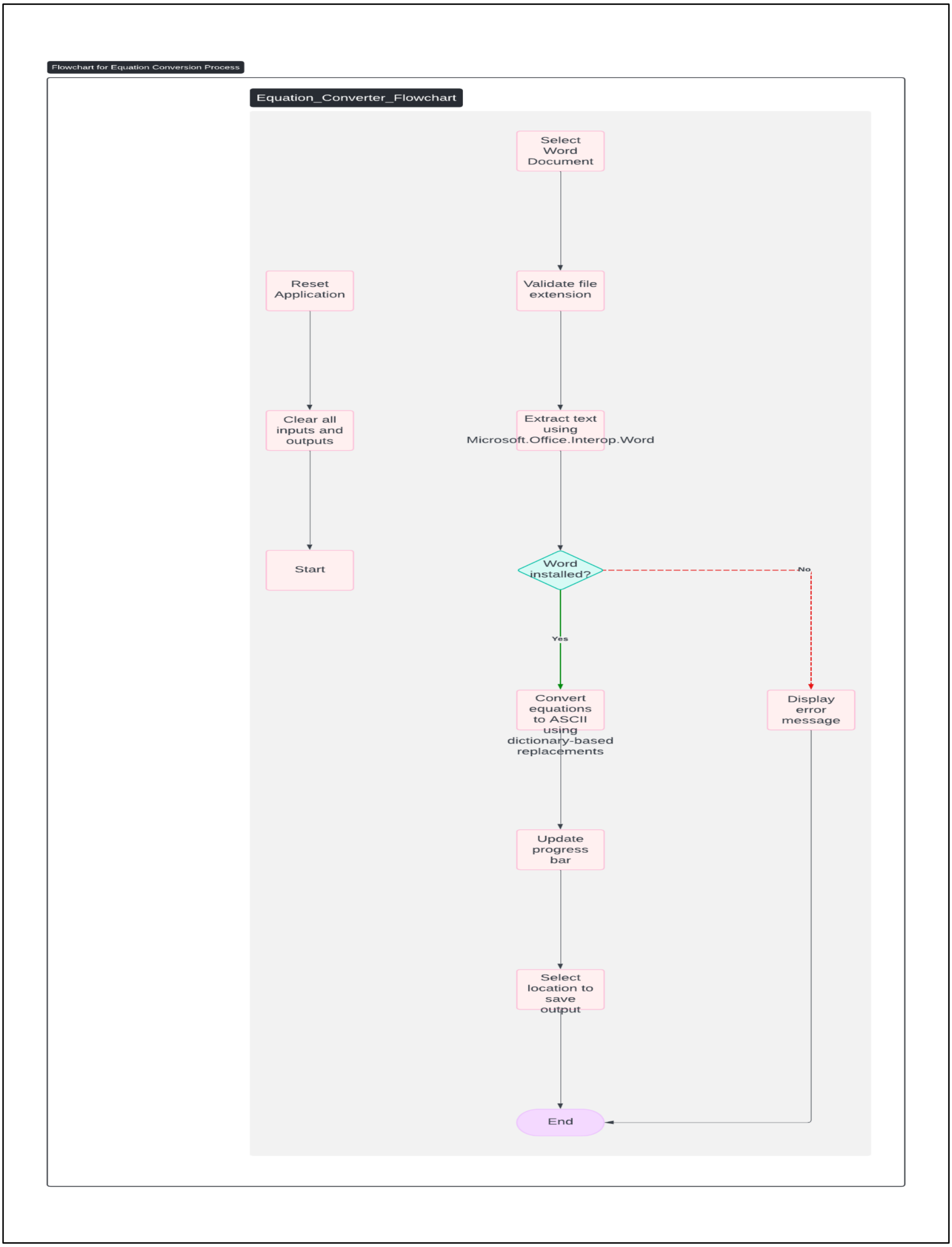

Fig 2: Flowchart of the Equation Converter

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➢ *The Interface of the Application*

The user interface is designed for simplicity, accessibility, and ease of use, with particular consideration for users who rely on assistive technologies. It features a Choose File button for selecting a Word document, a Convert button to initiate the conversion process, and a Save Output button that allows users to store the converted text. A Progress Bar provides real-time feedback during conversion, while a Reset button clears all loaded files and outputs, preparing the application for a new task. Additionally, a Status Messages Area displays important notifications, such as "File Loaded" or "Conversion Completed," ensuring users are informed at every stage

Fig 3: The Choose File Interface

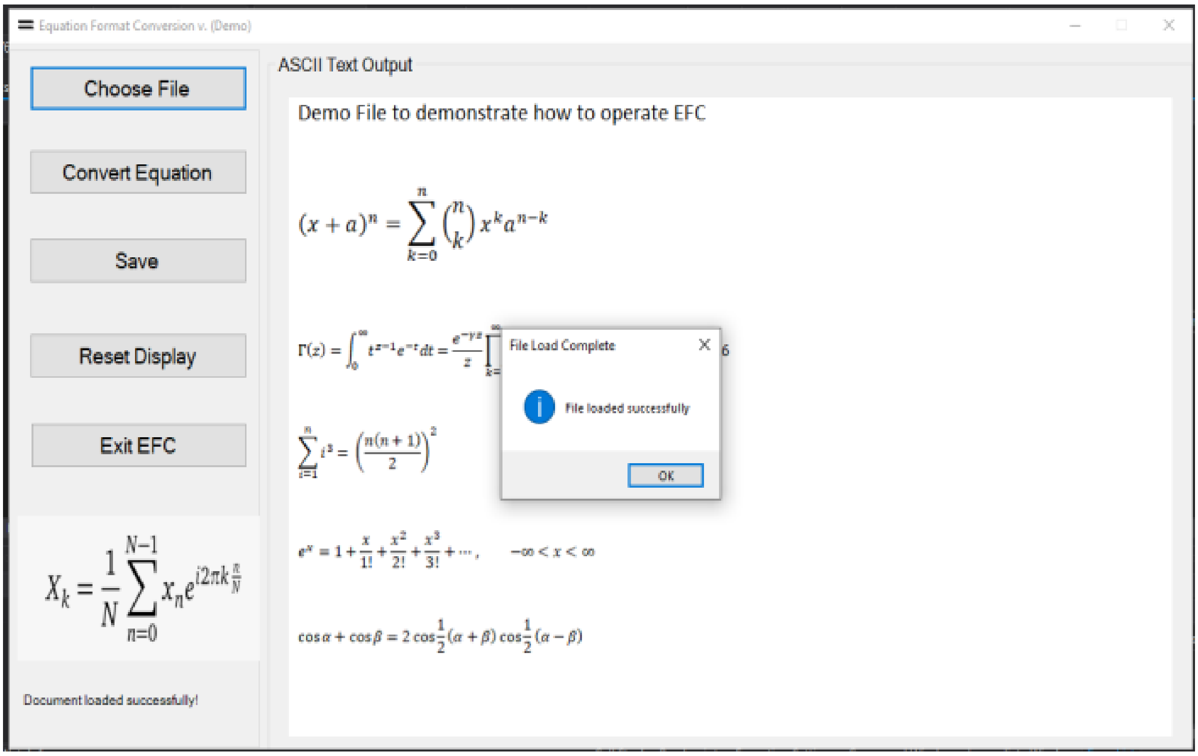

Fig 4: The Convert Equation Interface

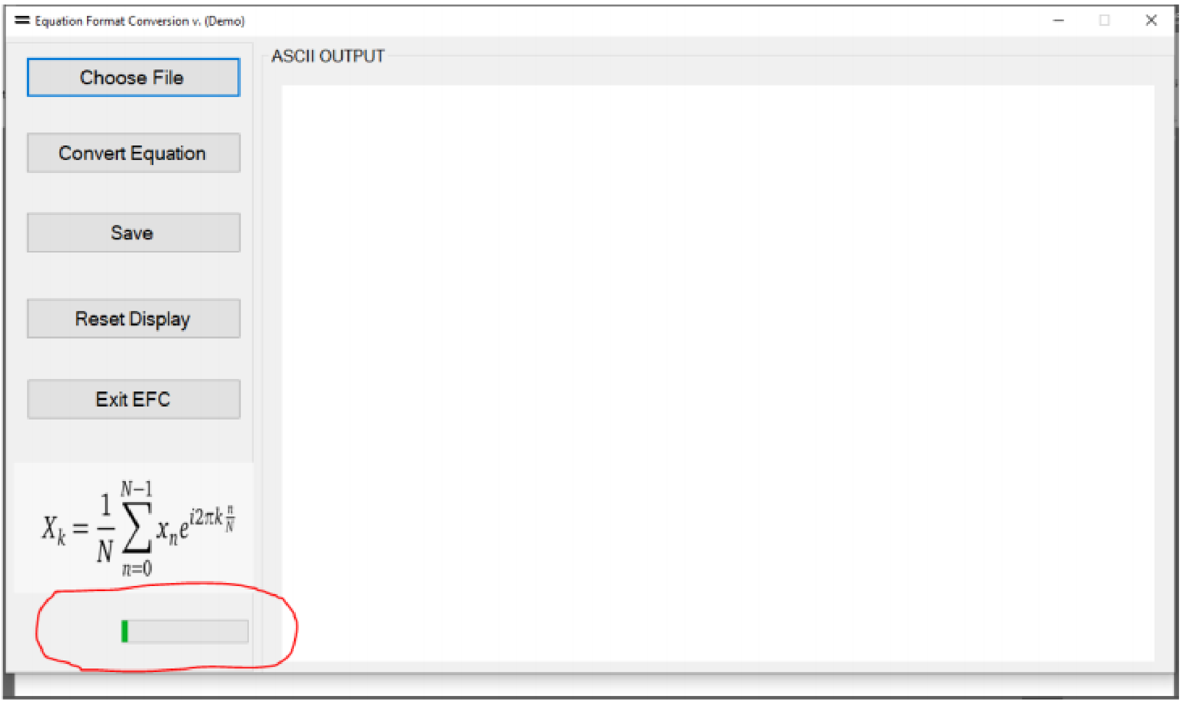

Fig 5: The Convert Equation Interface

➢ *Functional Testing*

Functional testing was carried out to ensure that each feature of the system performed according to its specifications. The File Loading Test verified that .doc and .docx files could be successfully loaded, while the Word Installation Check confirmed that the application accurately detects the availability of Microsoft Word. The Equation Conversion Test ensured that all Unicode mathematical symbols were correctly replaced with their ASCII equivalents, and the Progress Tracking Test validated that real-time updates were provided during file processing. The Output Saving Test confirmed that converted files were saved accurately to specified locations, and finally, the Reset Function Test verified that the system effectively cleared all inputs and returned to its initial state.

➢ *Usability Testing*

Usability testing involved observing BVI students as they navigated the interface using screen readers to assess ease of use and accessibility. Feedback was gathered from special education teachers on the practicality of integrating the software into teaching practices, focusing on its effectiveness in supporting inclusive STEM education. Additionally, the system was evaluated for compliance with accessibility best practices, including the provision of high-contrast visuals and full keyboard navigation, to ensure it meets the needs of users with visual impairments.

➢ *Testing Environment*

The testing environment consisted of Windows-based laptops equipped with at least 4GB of RAM and 500GB of hard disk storage, providing sufficient capacity for smooth software operation. The software setup included Microsoft Windows 10 or 11, Microsoft Word, and the NVDA screen reader to ensure compatibility with assistive technologies. A refreshable Braille display was also used to evaluate accessibility for blind and visually impaired users. Testing was conducted using 10 Word documents containing a variety of equations, ranging from simple arithmetic to advanced algebra and calculus, to assess the system's performance across different levels of mathematical complexity.

➢ *Evaluation Criteria*

Evaluation of the system was based on four key performance indicators. Accuracy Rate measured the percentage of equations correctly converted to ASCII format, while Processing Speed assessed the time taken to process each document. User Satisfaction was determined through feedback collected from post-test questionnaires, capturing the experiences of both BVI students and special education teachers. Finally, Accessibility Compliance evaluated the system's alignment with WCAG 2.1 Level AA standards, ensuring it met recognized guidelines for accessibility in digital applications.

IV. RESULTS

The results showed that the system achieved a 98% accuracy rate in converting equations correctly, with only minor errors observed in rare cases involving nested fractions. In terms of efficiency, the average processing speed for a 20-page document was 4.5 seconds, demonstrating fast and reliable performance. User satisfaction was high, with 92% of participants reporting that the system was easy to use and beneficial for their needs. Additionally, the software achieved full accessibility compliance, being fully compatible with the NVDA screen reader and Braille displays, while its high-contrast mode met WCAG accessibility guidelines.

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V. DISCUSSION OF FINDINGS

Testing confirmed that the Equation Converter Software performs reliably, efficiently, and accessibly. The high accuracy rate demonstrates the robustness of the Unicode-to-ASCII conversion algorithm. Positive feedback from teachers and students underscores its practical value in inclusive STEM education. The development of the equation converter software addresses a critical barrier faced by blind and visually impaired (BVI) students in accessing mathematics and science content. As highlighted by Adelakun et al. (2025), the inaccessibility of equations, symbols, and scientific notations in mainstream learning environments contributes to educational exclusion. Traditional assistive tools such as Braille and tactile graphics, while useful, often fail to adequately convey complex mathematical structures (Iyamuremye & Nsabayezu, 2023).

The equation converter bridges this gap by translating mathematical equations from Word documents into ASCII formats that are compatible with screen readers and Braille displays. This transformation aligns with the recommendations of Elshaer et al. (2025), who stress that digital learning solutions for BVI students must not only provide accurate content conversion but also ensure real-time interaction and feedback. By replacing symbols like ∑ with textual equivalents such as "sum," the converter enables learners to conceptualize mathematical expressions without reliance on visual cues, thus fostering independence and confidence in STEM learning.

Furthermore, the incorporation of Unicode-to-ASCII conversion addresses the challenges of diverse symbol encoding, which Kamaghe (2021) identifies as a major obstacle in developing universally accessible STEM materials. The software's design—employing local processing without the need for constant internet connectivity—also responds to infrastructural limitations in Nigerian schools, making it a viable solution in resource-constrained environments. However, limitations were noted in handling highly complex, multi-level mathematical structures, suggesting opportunities for future refinement.

VI. CONCLUSION

This research successfully developed and evaluated an Equation Converter Software designed to improve access to mathematical and scientific content for blind and visually impaired (BVI) students. The system demonstrated high accuracy in converting Unicode mathematical symbols to ASCII format, ensuring compatibility with screen readers and Braille displays. Testing confirmed its efficiency, accessibility, and ease of use, with positive feedback from both students and educators. By providing a low-cost, context-specific assistive technology solution, the software addresses a critical gap in inclusive STEM education in Nigeria. Its implementation has the potential to promote equitable learning opportunities, enhance digital accessibility, and empower BVI learners to engage more fully in academic pursuits.

RECOMMENDATIONS

Based on the findings of this research, the following recommendations are proposed:

- The Equation Converter Software should be deployed in special and inclusive schools across Nigeria to improve access to STEM content for BVI students.
- Special education and STEM teachers should be trained on how to use the software effectively, ensuring smooth integration into classroom instruction.
- Further development should focus on improving the handling of complex mathematical structures, such as nested fractions and multi-level equations, to achieve near-perfect accuracy.
- Government and educational policymakers should prioritize the provision of locally developed assistive technologies like this software as part of broader inclusive education initiatives.
- Future versions of the software should support additional document formats (e.g., PDF, LaTeX) and offer multilingual conversion to cater to diverse learning contexts.
- Partnerships with disability advocacy groups, ICT developers, and educational bodies should be fostered to scale up usage and ensure continuous feedback for improvement.

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