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Language Skills of Deaf Students Using the Computer Assisted Instruction (CAI) Application Program Model

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Abstract
Language skills are crucial for deaf students as they facilitate communication, education, and social integration. Without adequate language proficiency, deaf students face difficulties in academic learning and personal development. This research explores how the Computer-Assisted Instruction (CAI) application model enhances the language skills of deaf students by integrating technology-based learning tools. The study employs a Research and Development (R&D) approach using the ADDIE model—Analysis, Design, Development, Implementation, and Evaluation. The CAI model incorporates multimedia elements, including text, animations, videos, and interactive exercises, to enhance reading comprehension, writing abilities, and vocabulary acquisition. The program is designed using Macromedia Director and other supporting software to create an interactive learning environment tailored for deaf students. Findings indicate that the CAI model significantly improves reading comprehension, writing skills, and vocabulary retention. Students show increased motivation, engagement, and self-paced learning abilities. Teachers report improved student participation and communication through visual-based learning tools. However, challenges such as accessibility to digital resources and teacher training need to be addressed. The study

highlights CAI's effectiveness in promoting inclusive education for deaf students. Future research should explore AI-driven adaptive learning, gamification, and real-time speech-to-text translation to further enhance digital learning for deaf students. The integration of CAI in special education presents a transformative approach to improving language skills and educational outcomes for deaf learners.

Keywords: Language Skills, Deaf Students, Computer-Assisted Instruction (CAI), Application Program, Model.

Introduction

Language skills are essential for all individuals, including deaf students, as they serve as a fundamental tool for communication, education, and social interaction (Alothman, 2021). Without adequate language skills, deaf students may struggle to express their thoughts, understand others, and engage in meaningful conversations. Language acquisition plays a crucial role in their cognitive and emotional development, allowing them to build relationships, gain knowledge, and participate actively in society (Bai and Bruno, 2020; Graham and Shuler-Krause, 2020).

One of the primary reasons language skills are crucial for deaf students is that they enable effective communication (Alanazi, 2021). Whether through sign language, written language, or assistive technologies, language helps them convey their ideas and understand information from others (Farooq, et al., 2021; Khan, et al., 2020). Without a strong foundation in language, deaf students may face difficulties in socializing and forming relationships with peers, teachers, and family members, which can lead to isolation and frustration. In an educational setting, language skills are vital for academic success (Agustin, et al., 2021). Deaf students who develop strong literacy skills in reading and writing can access educational materials, understand lessons, and complete assignments effectively (Livingston, 2021; Kelly, et al., 2022). This is particularly important in inclusive education, where deaf students learn alongside their hearing peers. Teachers must ensure that learning materials and teaching methods support the language development of deaf students to enhance their learning experience (Kang and Scott, 2021).

Language skills contribute significantly to the personal and professional growth of deaf students (Freitas, et al., 2022). In the modern world, the ability to read, write, and communicate effectively is necessary for career opportunities and independence. Deaf individuals who develop strong language skills have better chances of pursuing higher education and securing employment in various fields (Punch and Duncan, 2022). Language proficiency also empowers them to advocate for their rights and participate in decision-making processes (Bell and Reed, 2022). Another urgent aspect of language skills for deaf students is their impact on cognitive development. Research suggests that language is closely linked to thinking and problem-solving abilities (Matthews and Kelly, 2022). Deaf students who have a well-developed language system can analyze information, reason logically, and engage in critical thinking (Scott et al., 2023). This cognitive development is essential for their overall academic and life achievements, ensuring they can navigate challenges effectively (Conley et al., 2020).

Language skills are a fundamental necessity for deaf students, influencing their communication, education, personal growth, and cognitive development (Sahara et al., 2024). Many reports regarding teaching deaf students have been well-documented (Marasabessy, 2023; Stackus and Asnancie, 2024; Musayaroh et al., 2023). Schools and educators must prioritize language acquisition through accessible teaching methods and resources. By doing so, they can create an inclusive learning environment that empowers deaf students to thrive and reach their full potential in all aspects of life. Computer-Assisted Instruction (CAI) offers numerous advantages in modern education by integrating technology into the learning process (Mensah and Ampadu,

2024). CAI provides interactive and engaging learning experiences through multimedia elements such as text, graphics, animations, and audio, making lessons more appealing and effective (Abanyam and Terkuma, 2021). This method of instruction caters to various learning styles and helps students grasp complex concepts more easily.

One of the significant benefits of CAI is personalized learning. Unlike traditional teaching methods, CAI allows students to learn at their own pace, giving them the flexibility to review materials and repeat lessons as needed (Singh et al., 2023). This is particularly beneficial for students with different learning speeds and abilities, including those with special educational needs. Adaptive learning programs within CAI can also adjust difficulty levels based on a student's progress, ensuring a customized learning experience. Another advantage of CAI is its ability to enhance student motivation and engagement. The use of interactive elements such as quizzes, simulations, and educational games makes learning more enjoyable (Zainuddin et al., 2020). This interactive approach encourages active participation, reducing boredom and increasing students' willingness to learn (Dewaele and Li, 2021). Furthermore, instant feedback from CAI programs helps students identify mistakes and improve their understanding in real time.

CAI also improves accessibility and efficiency in education. With the availability of online learning platforms, students can access educational content anytime and anywhere, reducing the need for physical textbooks and classroom-based learning (Kumari and Maity, 2025). This is particularly beneficial for remote learners and individuals who may have limited access to traditional educational resources (Ali, 2020). Additionally, CAI reduces the workload of teachers by automating tasks such as grading assessments and tracking student progress. Computer-Assisted Instruction is a valuable tool that enhances the learning experience by providing personalized education, increasing engagement, and improving accessibility (Kaye and Ehren, 2021; Rogayan Jr et al., 2021). As technology continues to evolve, the integration of CAI in education will become even more essential, helping students achieve better learning outcomes while supporting educators in delivering effective instruction.

The novelty of this research lies in its exploration of how a Computer-Assisted Instruction (CAI) application program model specifically enhances the language skills of deaf students, a group that often faces challenges in traditional learning environments. Unlike previous studies that focus on general CAI applications, this research investigates tailored digital tools designed to improve reading, writing, and comprehension for deaf learners through interactive and adaptive learning features. Additionally, it highlights the potential of CAI in fostering inclusive education, providing a structured and engaging learning experience that accommodates the unique linguistic and cognitive needs of deaf students. By integrating modern technology with specialized language instruction, this study contributes new insights into the effectiveness of digital learning innovations for enhancing communication skills in deaf education.

This research aims to examine the effectiveness of the Computer-Assisted Instruction (CAI) application program model in enhancing the language skills of deaf students. It seeks to analyze how CAI supports the development of reading, writing, and comprehension abilities while improving communication and engagement in the learning process. Additionally, the study aims to identify the most effective features of CAI for language acquisition and assess its role in promoting an inclusive and accessible educational environment for deaf students. Through this research, insights will be provided on the potential of CAI to enhance language learning outcomes and support teachers in implementing technology-driven instruction.

Research method

The research method includes the research design, subjects, instruments, and data analysis. It can be described as follows. This study follows a Research and Development (RandD) methodology to design, develop, and evaluate a Computer-Assisted Instruction (CAI) application program model for enhancing the language skills of deaf students. Figure 1 show the process of research. The study adopts the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model, which ensures a systematic approach to instructional design and technology development.

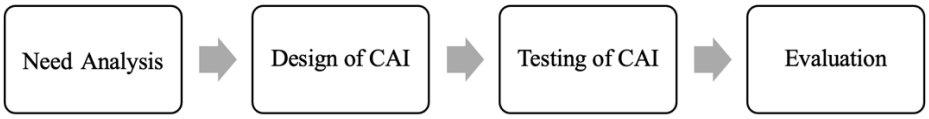

Figure 1. Process of research.

The image illustrates a structured development process for Computer-Assisted Instruction (CAI) through four sequential stages: Need Analysis, Design of CAI, Testing of CAI, and Evaluation. Each stage is crucial to ensuring that the CAI system effectively supports learning objectives and user needs. The process begins with Need Analysis, where developers identify the educational problems or gaps that the CAI will address. This phase involves gathering data about learners' needs, curriculum requirements, available technology, and any other relevant factors. The insights gained here form the foundation for the next phase, ensuring that clear, evidence-based goals drive the project. Following this, the Design of CAI stage involves creating the blueprint for the instruction system. This includes planning the user interface, selecting appropriate multimedia elements, outlining content delivery methods, and designing interactive features that will facilitate engagement and comprehension. A well-thought-out design is critical to maintaining users' attention and promoting meaningful learning experiences.

After the design phase is completed, the project moves into Testing of CAI. This stage focuses on examining the system's technical functionality as well as its educational effectiveness. Testing often begins with a pilot implementation, where a small group of target users interact with the CAI system. Feedback is collected on usability, accessibility, engagement levels, and learning outcomes. Any identified technical glitches or pedagogical shortcomings are corrected to refine the system before broader deployment. Testing is essential not only to ensure that the CAI operates smoothly but also to confirm that it genuinely helps users achieve the intended educational objectives. Finally, the process concludes with the Evaluation stage. Here, a comprehensive assessment is conducted to measure the CAI's success in real educational settings. Evaluators may use surveys, tests, interviews, and data analysis to gather evidence about the impact on learners' knowledge, skills, and attitudes. The results of the evaluation provide valuable insights into what aspects of the CAI were effective and where improvements are needed.

Overall, the image portrays CAI development as a logical, step-by-step process that emphasizes the importance of careful planning, rigorous testing, and continuous improvement. By following this sequence — from identifying needs, designing thoughtfully, testing thoroughly, and evaluating outcomes — developers can create high-quality instructional tools that significantly enhance teaching and learning experiences. Each stage is interconnected, with outputs from one stage feeding directly into the next, ensuring a coherent and responsive development cycle that aligns educational technology with real-world learning needs. The first phase involves a needs analysis to understand the challenges deaf students face in acquiring language skills. Data will be

gathered through interviews, surveys, and focus group discussions with special education teachers, deaf students, and experts in language development. This phase will help identify specific learning gaps, technological requirements, and preferred instructional strategies for deaf students.

Based on the findings from the needs analysis, the study will design a CAI application model tailored to the language learning needs of deaf students. The design will incorporate visual-based learning elements, sign language integration, interactive exercises, and adaptive learning features. A storyboard and prototype of the application will be developed, outlining the user interface, content structure, and learning flow. In the development phase, the CAI program will be built using educational technology tools and programming frameworks. The content will include reading, writing, and comprehension exercises, with multimedia elements such as animations, videos, and interactive quizzes to enhance engagement. The prototype will be tested internally by developers and instructional designers to ensure functionality and usability. Detailed information regarding this method is explained elsewhere (Susilawati et al., 2025).

After initial testing, the CAI application will be introduced to a selected group of deaf students in special education schools or inclusive classrooms. The implementation phase will last several weeks, during which students will use the application during language learning sessions. Teachers and facilitators will provide support and guidance to monitor the learning process. Table 1 shows the instruments for deaf students' language skills.

Table 1. Instrument for deaf student's language skill

Instrument	Purpose	Method of Assesment	Expected Outcome
Reading Comprehension Test	Assess ability to understand written text	Pre-test and post-test, multiple-choice, summarization tasks	Improved comprehension and ability to extract key information
Writing Skills Evaluation	Measure coherence, grammar, and structure in writing	Structured writing tasks, essay writing, sentence formation exercises	Improved sentence construction and writing clarity
Vocabulary Recognition Test	Assess word knowledge and usage	Matching words to meanings, vocabulary quizzes	Expanded vocabulary and correct word usage in context
Sign Language Fluency Assessment	Evaluate proficiency in sign language communication	Observation, peer interaction, expressive signing tasks	Increased fluency in sign language for communication
Listening and Lip-Reading Test	Assess ability to understand spoken language through lip-reading	Video-based exercises, real-time speech recognition	Improved ability to interpret lip movements and contextual meaning
Interactive CAI Engagement Analysis	Measure student interaction with CAI tools	System log analysis, tracking student engagement levels	Higher engagement and motivation in language learning
Teacher Observation Checklist	Evaluate student participation and communication in class	Classroom observations, structured rubrics	Increased student interaction and confidence in language use
Parent Survey and Feedback Form	Assess language development at home	Parent questionnaires, interviews	Enhanced parental involvement in language learning support

Peer Collaboration and Group Discussion Assessment	Evaluate student communication in social settings	Group activities, storytelling sessions, peer reviews	Increased confidence in collaborative language use
Self-Assessment and Reflection Journal	Allow students to reflect on their language progress	Written or video reflections, rating progress on language goals	Improved self-awareness and continuous language improvement

The table presents a variety of assessment instruments used to evaluate different aspects of language learning and student engagement, along with their purposes, methods of assessment, and expected outcomes. The Reading Comprehension Test assesses the ability to understand written text using pre-tests, post-tests, and summarization tasks, aiming to improve comprehension and information extraction. The Writing Skills Evaluation focuses on coherence, grammar, and writing structure through structured writing exercises, enhancing sentence construction and clarity. The Vocabulary Recognition Test uses matching and quizzes to assess word knowledge and usage, expanding vocabulary and correct contextual usage. Sign Language Fluency Assessment evaluates proficiency in sign language via peer interaction and expressive tasks, promoting better fluency in sign communication.

The Listening and Lip-Reading Test measures the ability to understand spoken language through real-time video exercises, improving interpretation of lip movements and contextual meaning. Interactive CAI Engagement Analysis examines student interaction with computer-assisted instruction tools by analyzing system logs and tracking engagement, resulting in higher motivation and participation. The Teacher Observation Checklist uses classroom observations and rubrics to evaluate student participation and communication, aiming to increase interaction and confidence. The Parent Survey and Feedback Form assesses language development at home through parent questionnaires and interviews, enhancing parental involvement in language learning.

Additionally, the Peer Collaboration and Group Discussion Assessment evaluates students' communication skills in social contexts through group activities and storytelling, boosting collaborative confidence. Lastly, the Self-Assessment and Reflection Journal allows students to reflect on their language learning progress through written or video reflections, fostering self-awareness and continuous improvement. Overall, this table highlights a comprehensive and multi-dimensional approach to assessing language skills, balancing individual, peer, teacher, and parent perspectives to support holistic student development.

Multiple data collection techniques will be used to assess the effectiveness of the CAI program, including pre-test and post-test assessments to measure improvements in students' language skills, observations of student interactions with the application, user experience feedback through surveys and interviews with students and teachers, and system log analysis to track engagement levels and learning progress within the application. The evaluation phase involves analyzing data from the implementation stage to determine the effectiveness of the CAI model. Quantitative analysis will be used to compare pre-test and post-test results, while qualitative data (from observations and interviews) will be thematically analyzed. Based on the findings, necessary improvements and refinements will be made to enhance the CAI program's usability and learning impact. To ensure the reliability and validity of the CAI application, feedback from educational technology experts, linguists, and special education professionals will be sought. Their insights will help refine the instructional design and ensure the program meets pedagogical and

accessibility standards for deaf students. After incorporating feedback from evaluations and expert reviews, a final version of the CAI application will be developed and prepared for broader use. The study will document the development process, findings, and best practices for integrating CAI into deaf education programs. The final product may be distributed to schools, special education centers, and online learning platforms to support inclusive education. This research aims to provide a practical and innovative solution for enhancing language skills in deaf students through technology. The findings will contribute to the field of educational technology and inclusive learning, offering recommendations for further improvements and future research in CAI-based language learning for students with hearing impairments.

Results

Based on the results, the average of students' writing ability of national insight-based text genres was still under the minimum standard of passing grade of writing topic of Indonesian language learning in university. There were 20% students, that were 6 of 30 students categorized in sufficient level. They able to write the national insight-based text genres in sufficient category, although there were some mistakes in writing. This category of students still needed the improvement in writing especially of national insight-based text genres. However, there were 80% students, that were 24 students categorized in less able in writing text genres. This category of students mostly had difficulty in writing. They were needed the improvement in writing text genres. In detail, the writing ability of national insight-based text genres consisted of students' ability to write descriptive, exposition, and procedure texts. The complete research results were described as follows.

CAI model development

The Computer-Assisted Instruction (CAI) application program model is designed to enhance the language skills of deaf students in special schools (SLB/B). Figure 2 show the design of model CAI. This model integrates various software tools to create an interactive and effective learning environment. The CAI application aims to improve students' reading, writing, and comprehension abilities through multimedia-based learning, making education more engaging and accessible for deaf learners.

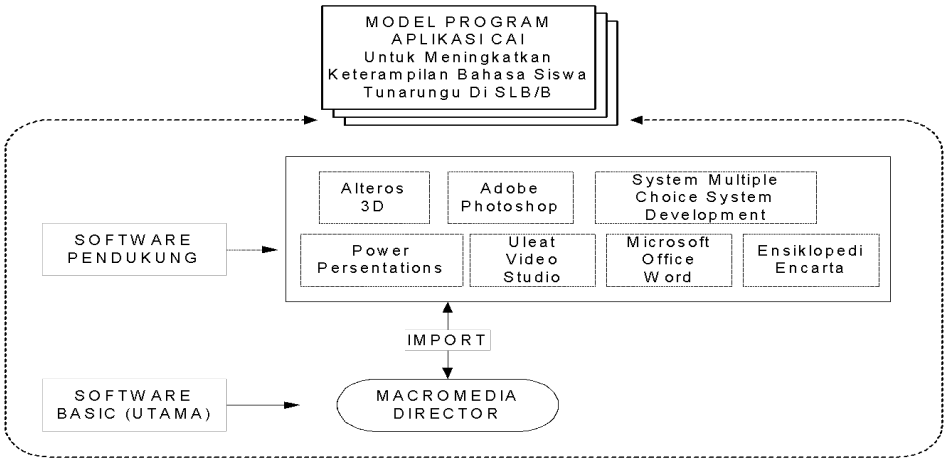

Figure 2. Design of model CAI

The figure illustrates a model framework for developing a Computer-Assisted Instruction (CAI) application aimed at enhancing the language skills of students with hearing impairments (Tunarungu) in special education schools (SLB/B). At the top, the diagram highlights the primary goal: designing a CAI program to support language learning. The development process is structured around the integration of basic and supporting software. The basic software used is Macromedia Director, a multimedia application authoring platform known for creating interactive educational content. This software acts as the core or main engine where various media elements are imported and integrated to build the CAI application.

Under the category of supporting software, several tools are listed that contribute to the creation of multimedia content. These include Alteros 3D for creating three-dimensional visualizations, Adobe Photoshop for editing images and creating graphics, and System Multiple Choice System Development for designing interactive multiple-choice assessments. Other tools such as Power Presentations help develop structured learning presentations, while Ulead Video Studio supports video editing and integration. Microsoft Office Word is used for text documentation and formatting content materials, and Ensiklopedi Encarta serves as a reference source for enriching educational content. All these supporting software products contribute specific media elements—whether visual, textual, or interactive—which are then imported into Macromedia Director for final compilation and assembly.

In summary, this diagram shows a collaborative process where multiple specialized software applications support the development of a comprehensive CAI program. Macromedia Director acts as the primary platform that synthesizes various multimedia elements into an interactive learning application designed specifically to meet the communication needs of deaf students. This model ensures that the resulting CAI program is rich, engaging, and accessible, thereby significantly enhancing the students' language acquisition experience.The development of this CAI program relies on a combination of primary and supporting software. The basic software (main software) used in the development is Macromedia Director, which serves as the core platform for creating interactive educational content. Macromedia Director allows for the integration of various media elements such as text, images, animations, and videos, making it a powerful tool for developing instructional applications tailored to the needs of deaf students. To enhance the effectiveness of the CAI program, several supporting software applications are utilized. These include Alteros 3D, which is used for creating three-dimensional visual elements to support interactive learning. Adobe Photoshop plays a crucial role in designing high-quality graphics and images, making the content visually appealing and accessible for students. Additionally, Power Presentations is used to create structured learning materials with clear visual representations to aid comprehension.

Another key component of the CAI model is the System Multiple Choice System Development, which is used to design interactive assessments and quizzes. This system helps evaluate students' understanding and progress in language learning. Furthermore, Ulead Video Studio is employed to develop video-based instructional content, incorporating sign language and subtitles to enhance comprehension for deaf students. The inclusion of Microsoft Office Word allows for the creation of written exercises, worksheets, and text-based instructional materials. An additional valuable resource in the CAI model is Encyclopedia Encarta, which provides a rich database of knowledge and reference materials. By integrating Encarta, students can access a wide range of educational content that supports their language development. The combination of these supporting software tools ensures that the CAI application is comprehensive, engaging, and effective in improving language skills.

The CAI application follows an import process, where various multimedia and instructional elements created using the supporting software are integrated into Macromedia Director. This allows for the seamless combination of graphics, animations, videos, and interactive exercises into a single, cohesive learning platform. By utilizing this structured approach, the CAI program offers a modern, technology-driven solution to support the language development of deaf students, fostering an inclusive and interactive educational experience. The CAI program featured interactive storybooks that engaged students with visually appealing content. These storybooks included animations, images, and text that helped students connect meaning to words more easily. By presenting information in a structured and interactive format, students were able to follow narratives more effectively and retain key concepts. Another feature of the CAI program was visual storytelling, which played a crucial role in enhancing comprehension. Instead of relying solely on written words, visual storytelling used pictures, symbols, and animations to illustrate ideas. This approach helped students understand the context of stories without requiring extensive text interpretation, making reading more accessible and enjoyable.

Students' language skill of deaf learning using CAI model

The implementation of the Computer-Assisted Instruction (CAI) application program model has shown significant improvements in the language skills of deaf students. The results indicate that integrating multimedia-based learning has positively impacted reading comprehension, writing abilities, vocabulary acquisition, and communication skills. Through structured assessments and observations, it was evident that students demonstrated greater engagement and motivation in their learning process. Before using the CAI model, many deaf students struggled with understanding written text, sentence structure, and expanding their vocabulary. Traditional teaching methods often lacked the necessary visual and interactive elements that cater to the learning needs of deaf students. However, after implementing the CAI application, there was a noticeable improvement in word recognition, sentence formation, and contextual understanding.

Reading comprehension

One of the most significant improvements observed in the study was in the reading comprehension skills of deaf students. Reading comprehension is essential for academic success, many deaf students struggle with understanding written text due to differences in language acquisition. The integration of Computer-Assisted Instruction (CAI) provided an effective solution by incorporating various interactive learning elements. Table 2 show the deaf student's reading comprehension.

Table 2. Deaf student's reading comprehension

Assessment Criteria	Before (%)	After (%)	Improvement (%)
Understanding Written Text	40	75	35
Identifying Key Information	45	80	35
Summarizing Passages	38	78	40
Retention of Concepts	42	82	40
Engagement with Storybooks	50	85	35
Comprehension via Visual Storytelling	48	83	35
Understanding Sign Languange Integration	55	88	33

As a result of these interactive and visually enriched learning methods, students who initially struggled with complex sentences showed significant progress. They demonstrated an improved ability to identify key information, summarize passages, and extract meaning from texts. The CAI program proved to be an effective tool in strengthening reading comprehension among deaf students, making language learning more engaging and inclusive.

Writing skills

In terms of writing skills, the CAI model provided students with structured writing exercises, visual prompts, and guided sentence-building activities. Many students who previously struggled with forming coherent sentences were able to construct clearer and more grammatically accurate written responses. The interactive exercises allowed them to practice word ordering, sentence construction, and paragraph development at their own pace.

Another key area of improvement was vocabulary acquisition. The CAI program utilized animated vocabulary drills, image-based word association activities, and multimedia-enhanced definitions, making it easier for deaf students to expand their word bank. Students exhibited greater confidence in recognizing and using new words in different contexts, which contributed to their overall language proficiency. Table 3 show deaf student's wirting skills.

Table 3. Deaf student's wirting skills

Assessment Criteria	Before (%)	After (%)	Improvement (%)
Sentence Contsruction	42	78	36
Grammar Accuracy	40	76	36
Vocabulary Recognition	45	82	37
Writing Coherence and Clarity	38	75	37
Engagement with Interactive Writing Tools	50	85	35
Self-Paced Learning	48	83	35
Peer Collaboration in Writing Task	52	86	34
Teacher-Student Interaction Improvement	49	84	35
Parental Observation of Learning at Home	44	81	37

The use of visual-based learning tools such as 3D animations, sign language video tutorials, and gamified learning activities played a crucial role in maintaining student engagement. Unlike conventional methods that rely heavily on written explanations, the CAI model provided a more inclusive and stimulating learning experience, reducing frustration and enhancing retention of new concepts.

Observations also indicated an improvement in self-paced learning abilities. Since the CAI program allowed students to navigate through lessons independently, they developed greater autonomy and self-confidence in their learning journey. Teachers reported that students became more proactive in exploring different language exercises and showed increased enthusiasm in completing assignments.

Assessments conducted before and after the implementation of the CAI program revealed a statistically significant improvement in test scores. The pre-test results indicated that many

students had difficulty with basic reading and writing tasks, whereas the post-test results showed marked progress in comprehension, sentence structuring, and vocabulary use.

Interviews with teachers and special education professionals confirmed that the CAI application provided a more effective and engaging approach to language instruction. Teachers noted that students were more attentive, motivated, and willing to participate in class activities compared to traditional teaching methods. The use of visual and interactive elements helped bridge the gap between sign language and written language, making learning more accessible.

Continuity of receptive and expressive language of deaf students.

Language development in deaf students follows a unique trajectory, particularly in terms of receptive and expressive language. Receptive language refers to the ability to understand and comprehend language, while expressive language involves the ability to convey thoughts, emotions, and ideas through spoken, written, or signed communication. The development of these skills is crucial for academic achievement, social interaction, and overall cognitive growth. However, deaf students often face challenges in maintaining continuity in these aspects due to limitations in auditory input. Table 4 shows the continuity of the receptive and expressive language of deaf students.

Table 4. Continuity of receptive and expressive language of deaf students.

Assessment Criteria	Before (%)	After (%)	Improvement (%)
Receptive Languange Comprehension	45	80	35
Understanding Sign Languange Concept	50	85	35
Written Languange Comprehension	42	78	36
Expressive Languange Fluency	40	76	36
Sentence Structure and Grammar in Writing	38	75	37
Participation in Discussions and Storytelling	44	80	36
Confidence in Expressing Thoughts	41	79	38
Family Involvement in Languange Development	48	83	35
Engagement with Assistive Technology	46	82	36
Accessibikity and Inclusivity in Education	43	81	38

For receptive language, deaf students primarily rely on visual input, such as sign language, lip-reading, written text, and visual cues. Unlike hearing students who acquire language naturally through auditory exposure, deaf students must receive explicit and structured language instruction. The continuity of receptive language development depends on early language exposure, access to effective teaching strategies, and the availability of communication resources that support their learning needs.

Sign language plays a critical role in receptive language development, serving as a primary mode of communication for many deaf individuals. When introduced early, native sign language acquisition can enhance a student's ability to understand complex concepts, follow instructions, and engage in meaningful conversations. However, for students who do not have access to sign language from an early age, receptive language development may be delayed, leading to difficulties in academic learning and social communication.

In addition to sign language, written language serves as an essential component of receptive language. Deaf students often face challenges in reading comprehension, as they may struggle with

syntax, grammar, and vocabulary that differ from their primary sign language. Bridging the gap between sign language and written language requires specialized teaching approaches, such as visual storytelling, multimedia-based learning, and bilingual education.

The continuity of receptive language development is also influenced by educational technology, such as Computer-Assisted Instruction (CAI), captioned videos, and digital reading tools. These resources provide deaf students with interactive and engaging methods to improve their comprehension skills. Research shows that incorporating visual-based learning into language instruction enhances information retention and understanding, promoting a smoother transition from sign language to written language.

On the other hand, expressive language development refers to a student's ability to communicate thoughts and ideas effectively. For deaf students, expressive language can be conveyed through sign language, written expression, gestures, or speech (if they use assistive hearing devices or speech therapy). Developing continuity in expressive language requires consistent practice, language modeling, and opportunities for interaction.

A significant challenge in expressive language continuity is the limited exposure to fluent language models, particularly for deaf students in non-signing environments. In mainstream schools where teachers and peers do not use sign language, deaf students may struggle to express themselves clearly and participate in discussions. Providing accessible communication methods, such as sign language interpreters, visual aids, and text-based communication tools, is essential for maintaining expressive language development.

Written expression is another crucial aspect of expressive language development for deaf students. Many face difficulties with complex sentence structures, grammar, and word order, particularly when transitioning from sign language to written text. The use of structured writing exercises, peer collaboration, and digital tools can support the continuity of written language development, allowing students to refine their storytelling, essay writing, and creative expression skills.

Expressive language skills are also reinforced through interactive learning environments, such as group discussions, storytelling sessions, and multimedia presentations. Encouraging deaf students to participate in conversations, express opinions, and narrate experiences fosters greater confidence and fluency in both sign language and written communication.

Another factor influencing continuity in expressive and receptive language development is family involvement. Deaf students who grow up in signing households tend to develop stronger language skills compared to those in non-signing environments. Parents who actively engage in sign language communication, read with their children, and support language-rich interactions contribute to consistent and continuous language growth.

Discussion

The program integrated sign language-supported explanations to aid comprehension. Many deaf students rely on sign language as their primary mode of communication, and incorporating it into the CAI program allowed them to bridge the gap between written text and their existing language skills. This method reinforced understanding and helped students make connections between sign language and written language. Student feedback also highlighted the benefits of using CAI. Many students expressed that learning with multimedia content was more enjoyable and easier to understand compared to traditional textbooks. The inclusion of sign language videos and interactive exercises helped them grasp new concepts more effectively, leading to greater confidence in using written language (Ngobeni et al., 2020). Another important outcome was the

increase in collaborative learning. The CAI model facilitated peer discussions and group activities, where students engaged in interactive quizzes, storytelling exercises, and writing tasks together. This fostered a sense of community and shared learning, encouraging students to support each other in improving their language skills (Lomicka, 2020).

The impact of CAI was also evident in teacher-student interactions. Teachers were able to use the CAI platform to personalize lessons, provide real-time feedback, and track student progress more efficiently. The availability of digital learning resources enabled educators to tailor instruction to meet the individual needs of each student, ensuring that no one was left behind (Tate and Warschauer, 2022).

The integration of multiple-choice assessment tools within the CAI application allowed teachers to evaluate students' learning progress more accurately and systematically. The automated feedback system helped students understand their mistakes immediately, enabling faster correction and reinforcement of concepts. Parental feedback further supported the effectiveness of the CAI model. Parents observed that their children became more interested in reading and writing at home, often practicing language exercises independently. The increased engagement with language learning extended beyond the classroom, demonstrating the long-term benefits of technology-assisted education (Hao et al., 2021). The findings of this study provide strong evidence that CAI is a valuable tool for addressing the unique language learning needs of deaf students. Moving forward, the continued development and expansion of technology-assisted learning in special education will play a crucial role in empowering students with hearing impairments to achieve greater language proficiency and academic success (Balachandran and Rabbiraj, 2025; Sriwisathiyakun and Dhamanitayakul, 2024).

The role of bilingual education is also significant in ensuring continuity in both receptive and expressive language development (Erdemir, and Brutt-Griffler, 2022). Approaches that incorporate both sign language and written language instruction help deaf students become fluent in multiple language modalities, allowing them to navigate academic settings and social interactions with greater ease (Wainscott and Spurgin, 2024). Educational institutions must adopt inclusive policies and teaching strategies to promote language continuity (Sorkos and Hajisoteriou, 2021). Schools that provide sign language courses, trained educators, assistive technologies, and visual learning materials create a more accessible and supportive learning environment for deaf students, ensuring consistent language development.

Despite these efforts, challenges remain in ensuring language continuity beyond the classroom. Deaf students often face communication barriers in mainstream society, which can hinder their ability to practice and maintain their expressive and receptive language skills (Todorov et al., 2022). Promoting public awareness, workplace accessibility, and social inclusion initiatives can help create a more language-friendly environment for deaf individuals (Napier et al., 2022).

The continuity of receptive and expressive language development in deaf students is influenced by early language exposure, educational strategies, technological resources, family involvement, and societal accessibility. Ensuring that deaf students have access to language-rich environments, inclusive education, and continuous opportunities for communication is essential for their academic success and personal growth (Walsh, 2024). By integrating bilingual education, assistive technology, and interactive learning approaches, educators and caregivers can support sustained language development in deaf students, empowering them to thrive in both academic and social settings (Habibi et al., 2025).

Despite the positive results, some challenges were also identified. A few students required additional guidance in navigating the digital interface of the CAI program, indicating a need for

better user training and accessibility features. Teachers also highlighted the importance of balancing screen time with hands-on activities to prevent over-reliance on digital learning. Another limitation was the availability of technological resources in some schools. Not all institutions had the necessary hardware and internet connectivity to fully implement the CAI program. Addressing these challenges requires greater investment in educational technology and teacher training programs to ensure widespread accessibility.

Future research could explore ways to enhance the CAI application by incorporating artificial intelligence (AI) for adaptive learning, real-time speech-to-text translation tools, and gamification elements to further improve engagement and effectiveness. Additionally, expanding the program to include more advanced language learning levels could benefit a broader range of students. The implementation of the CAI application model has demonstrated significant improvements in the language skills of deaf students. The integration of visual, interactive, and multimedia-based learning has made language acquisition more engaging, effective, and accessible. By leveraging educational technology, this approach has the potential to revolutionize language education for deaf students and create a more inclusive learning environment.

Conclusion

The study on the Computer Assisted Instruction (CAI) application program model demonstrates its effectiveness in enhancing the language skills of deaf students. Language acquisition is essential for deaf students' communication, education, and social development, yet traditional teaching methods often fail to accommodate their unique learning needs. By integrating interactive and multimedia-based learning tools, the CAI model provides a structured, engaging, and accessible approach that significantly improves their reading comprehension, writing skills, and vocabulary acquisition. The implementation of the CAI program resulted in remarkable improvements in students' reading comprehension. Many deaf students initially struggled with understanding complex sentences and extracting key information from texts. However, with the help of interactive storybooks, visual storytelling, and sign language-supported explanations, they became more adept at summarizing passages and recognizing essential details. The use of multimedia content—such as animations, sign language videos, and interactive exercises—allowed them to bridge the gap between sign language and written language, enhancing their overall comprehension.

In terms of writing skills, the CAI program enabled students to practice sentence structuring, grammar, and word formation through guided exercises and visual prompts. Many students who initially had difficulty constructing coherent sentences showed progress in forming grammatically accurate and well-structured written responses. The integration of gamified learning activities and structured writing tasks encouraged self-paced learning, allowing students to develop confidence in their writing abilities. Additionally, vocabulary acquisition improved as students engaged with animated vocabulary drills, image-based word association exercises, and multimedia-enhanced definitions. The interactive nature of the CAI model helped students retain and apply new words more effectively in different contexts. One of the most significant contributions of the CAI model is its ability to increase student engagement and motivation. Traditional classroom methods often fail to provide the visual and interactive components that deaf students need for effective learning. The CAI program addressed this by offering interactive quizzes, digital storytelling, and real-time feedback, which kept students actively involved in the learning process. Teachers also reported an increase in peer collaboration as students participated in group activities, discussions, and storytelling exercises facilitated by the CAI model. This

collaborative environment not only improved language skills but also strengthened social interactions among deaf students.

Despite its success, several challenges were identified in the implementation of the CAI model. Some students required additional guidance in navigating the digital interface, suggesting the need for improved user training and accessibility features. Teachers also emphasized the importance of balancing screen time with hands-on activities to avoid over-reliance on technology. Additionally, infrastructure limitations in some schools, such as lack of hardware and internet access, posed barriers to full-scale implementation. Addressing these challenges requires investment in educational technology, teacher training programs, and policy support to ensure broader accessibility. Overall, this research highlights the transformative potential of CAI in improving language skills and promoting inclusive education for deaf students. By leveraging technology-driven learning, the CAI model provides a structured, engaging, and accessible approach that can be further developed with artificial intelligence (AI), adaptive learning features, and gamification. Moving forward, the continued integration of digital learning tools in special education will play a crucial role in empowering deaf students to achieve greater language proficiency, academic success, and social participation.

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