

## AUTOMATED SPEECH RECOGNITION TRANSCRIPTION AND SIGN LANGUAGE CHARACTER ANIMATION ON LEARNING MEDIA

### RECONHECIMENTO AUTOMATIZADO DE FALA, TRANSCRIÇÃO E ANIMAÇÃO DE CARACTERES EM LÍNGUA DE SINAIS EM MÍDIAS DE APRENDIZAGEM

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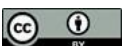
#### Abstract

The current study aimed at developing Real-Time Automated Speech Recognition with Sign Language Character Animation for teaching deaf students at SLBN 1 Gianyar Bali. The development was conducted by adapting ADDIE model consisting of; analysis, design, development, implementation, and evaluation. There were 21 deaf students, 2 teachers, and 5 experts involved as research subjects. The data were collected through questionnaire, interview, test, and notes. The data were analyzed qualitatively and quantitatively. The results of the study show that the developed learning media are valid, feasible, and effective to improve learning outcomes of the deaf students. The study implies that learning media with real-time Automated Speech Recognition transcription and sign language character animations is beneficial for deaf students in the learning process.

**Keywords:** ASR. Deaf Students. Learning Media.

#### Resumo

*O presente estudo teve como objetivo desenvolver um sistema de reconhecimento automático de fala em tempo real com animação de caracteres em linguagem de sinais para o ensino de alunos surdos na SLBN 1 Gianyar Bali. O desenvolvimento foi realizado através da adaptação do modelo ADDIE, que consiste em: análise, projeto, desenvolvimento, implementação e avaliação. Participaram da pesquisa 21 alunos surdos, 2 professores e 5 especialistas. Os dados foram coletados por meio de questionários, entrevistas, testes e anotações. Os dados foram analisados qualitativa e quantitativamente. Os resultados do estudo mostram que os meios de aprendizagem desenvolvidos são válidos, viáveis e eficazes para melhorar os resultados de aprendizagem dos alunos surdos. O estudo sugere que os meios de aprendizagem com transcrição de reconhecimento automático de fala em tempo real e animações de caracteres em linguagem de sinais são benéficos para os alunos surdos no processo de aprendizagem.*



*Palavras-chave:* ASR. Alunos Surdos. Meios de Aprendizagem.

## 1 INTRODUCTION

Special Educational Needs is specifically designed for providing educational services for the students who encounter significant challenges in regular learning process due to their physical, emotional, mental, or social impairments (Agung et al., 2022; Mansur et al., 2023; Nasution et al., 2022). Indonesian government regards Special Educational Needs as an alternative to conduct inclusion class for the students who have different learning needs in which the facilities are functioned differently to fulfil the students' needs in which it aims at ensuring that all individuals deserve equal opportunities in education (Khairuddin, 2020; Saadah & Harsiwi, 2024). It indicates that Special Educational Needs is specialized for students who cannot be effectively accommodated within general education programs in which it needs specialized curricula, instructional materials, assistive devices, and teaching strategies (Hornby, 2011). Consequently, the design of learning in special education settings must be flexible, adaptive, and student-cantered, ensuring that educational practices are aligned with the individual characteristics and learning capacities of students.

Among various students' groups in Special Educational Needs, deaf students are the ones who experience complex learning challenges considering that they have lack communication barriers. They have limited or absent hearing ability that significantly influences their language acquisition which becomes the most fundamental instruction in the learning process (Gunawan, 2016). As a result, deaf students are often struggling in expressing their ideas, emotions, and learning needs through verbal communication as well as comprehending spoken information during their interaction with the teachers or peers (Elez & Martín, 2022). These limitation not only impacts students' academic learning but also restricts students' social interaction and potentially leading them to feel isolated. Therefore, teachers in Special Educational Needs are supposed to teach deaf students by comprehensively understanding students' linguistic, cognitive, and socio-emotional characteristics of the students.

A relevant problem is found during the preliminary observation at SLBN 1 Gianyar Bali. It is found that the inclusion classrooms indicating the same problem related

to communication difficulties faced by the teachers in interacting with deaf students. The teachers are able to communicate with students by using Signed Indonesian System (SIBI) but it is still lack of comprehensive which reduces their social interaction. In addition, inadequate technology-based learning resources exacerbates these challenging. The teachers mention that without adequate technological support, deaf students are frequently struggling in following the lesson content, participating in discussions, and developing essential skills required for academic and personal growth. These findings highlight an urgent need for innovative technology-based learning media to support the learning process at SLBN 1 Gianyara particularly in teaching deaf students.

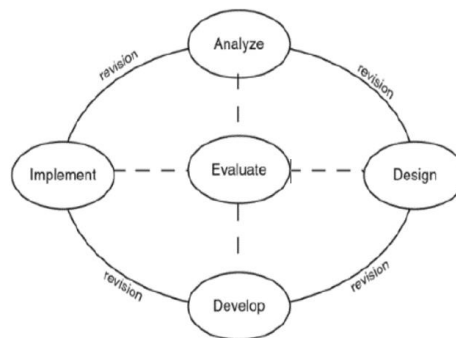
In this digital era, the integration of information and communication technology (ICT) into classrooms has become increasingly essential to enhance learning accessibility and effectiveness. Real-Time Automated Speech Recognition (ASR) is one of ICT integration highly potential to help both teachers and deaf students in interacting during the learning process in which it transforms humans' speech into written texts (Aji & Aeman, 2023a; Carrier, 2017). It is an application processing natural language involves many stages including audio recording, pre-processing, feature extraction, ASR modelling, decoding, and error correction (Arakawa et al., 2022). Real-Time ASR is continuously developed along with deep learning and larger training dataset development allowed the users to conduct natural interaction and improve the efficiency of speech recognition (Zhang et al., 2023a). In addition, ASR can be integrated with sign language character animation that is perceived as a strategic solution to address the current challenges in Special Educational Needs. Real-time ASR technology enables spoken language to be automatically converted into text, while sign language character animation provides visual representation of instructional content in a form that is accessible to deaf students (Verlinden et al., 2005). The integration of these technologies allows educators with diverse educational backgrounds and varying levels of sign language mastery to effectively deliver learning materials (Nasri, 2020). Moreover, such learning media can enhance students' comprehension, participation, and engagement in the learning process. Ultimately, this innovation is expected to contribute to more inclusive, accessible, and effective learning experiences for deaf students in special education settings (Widiartha et al., 2024).

Many studies have explored the technological integration in Special Educational Needs. Pradipta et al., (2021) emphasize teachers' professionalism in managing ICT-

based learning for deaf students by using computer-based information technology, infrastructure availability, and teachers' competencies in designing and managing learning media. It is relevant to the study conducted by Mabruroh and Widyastono (2022) showing that e-learning module is effective to improve deaf students' self-regulated learning. An earlier study highlights that adaptive audio-visual learning is also effective to improve learning motivation, comprehension, and engagement among special needs students (Ramadania et al., 2020). Ratriyana and Nuswantoro (2022) develop communication media for deaf students without incorporate real-time speech recognition. It is found that the media is effective but needs further development is required. These studies demonstrate that technology integration in inclusive classrooms are effective although there is still lack of exploration on the integration of Real-Time Auto Speech Recognition (ASR). Wilyanti et al., (2022) investigated the automated speech recognition and transcription technologies in contexts such as healthcare and cultural preservation, demonstrating the significant potential of speech-to-text technologies, but without direct application to inclusive learning environments for deaf students. It indicates that speech recognition is potential but needs an exploration in inclusion classrooms. Therefore, the current study is conducted to develop a learning media that **integrates real-time Automated Speech Recognition (ASR) transcription with sign language character animation** for deaf students at SLBN 1 Gianyar, Bali. The study also intends to find out the quality and effectiveness of developed product for teaching and learning process in Special Educational Needs.

## 2 METHOD

The model used in this study is the ADDIE instructional design model (Analyze, Design, Develop, Implement, and Evaluate). Branch, R. M. describes the stages of the ADDIE instructional design model as follows (Branch, 2009).

**Figure 1***ADDIE Model Design Stages*

Analysis Phase. The researcher understood the problem or educational need that would be addressed through learning media with real-time ASR (Automated Speech Recognition) transcription and sign language character animation, which involved identifying the purpose of developing the learning media, the users of the teaching media, and the context in which learning would take place. It began with collecting relevant data and information, including interviews with educators, classroom observations of learning in progress, and an analysis of the existing curriculum and materials. Furthermore, the researcher details how learning media would be built based on the findings and objectives collected during the Analysis phase. At the design stage, the product with real-time ASR (Automated Speech Recognition) transcription and sign language character animation was designed. Then, at the development stage, the product was developed into a real learning media. Next, the product was implemented in the classroom. Finally, the evaluation of the developed product was examined from the results of the learning outcomes. The subjects of the study were 2 teachers and 21 deaf students, and 5 experts. They were selected to determine the needs of the students as well as to evaluate the developed product. Some instruments were distributed to collect the data, namely; questionnaire, interview guide, test, and notes. They were used to collect information about students' needs and effectiveness of the developed product. The data were analysed qualitatively and quantitatively.

### 3 RESULTS

The present study has developed learning media with real-time Automated Speech Recognition transcription and sign language character animations, specifically designed to facilitate the learning of deaf students. The development of the learning media is described as follows.

#### 3.1 Analysis

In this stage, the study is concerned with the three aspects, namely need analysis, curriculum analysis, and deaf students analysis. Firstly, a needs analysis was conducted to meet the needs of deaf students. The analysis involved identifying the dependence of deaf students on teachers who master sign language, as well as the limited human resources competent in sign language, and the accessibility of technology to access learning materials for deaf students. The analysis was obtained from the results of an interview with the teacher. It was revealed that many deaf students had difficulty understanding verbal instructions delivered directly by teachers, especially if the teacher did not master the sign language. It indicated that a primary need was the development of media capable of converting speech into text and displaying sign language visualizations, allowing students to participate in learning independently without communication barriers. Secondly, the curriculum analysis was also conducted to examine the competency standards and relevant learning materials based on the applicable curriculum. This analysis was beneficial to determine the content and concepts that needed to be included in the learning media. By aligning the media with the curriculum, learning media could support the achievement of educational objectives more effectively. The material presented in the learning media focused on the animal life cycle as one of the learning themes in the Natural Sciences subject, which included the stages of complete and incomplete metamorphosis. This topic was selected based on the applicable curriculum and the results of a needs analysis, which indicated that deaf students experience difficulties in understanding the concept of changes in living things. Therefore, the material was presented in text form that could be transcribed and visualized with sign language animations, which facilitated a more concrete understanding of the concept. Lastly, deaf students' characteristics were also identified to understand their abilities, limitation, and their needs in the learning process.

Deaf students generally visualize things to understand information, so the learning media focused on providing clear visualization and text as well as the way of using the media, since deaf students were slow to understand the learning materials. From the analysis, learning media were designed for deaf students in order to access the learning materials easily. In conclusion, at the analysis stage, it is revealed that learning media that can help to visualize information, assisting deaf students in understanding the learning materials, needs to be developed to meet their needs in the learning process.

### **3.2 Design**

From the results of the Analysis stage, the prototype was designed to meet students' needs. In the present study, learning media with real-time Automated Speech Recognition transcription and sign language character animations were designed as the prototype of the study, which were based on the needs of deaf students. This design was carried out by considering several important aspects in developing technology-based learning media, including: learning flow, user interface (UI/UX), utilization of Progressive Web Apps (PWA), SIBI sign language, ASR technology design, and database design.

### **3.3 Development**

After designing the prototype, it was developed into learning media with Real-Time ASR Transcription and Sign Language Animation that can be used by deaf students. The development process can be seen as follows.

The frame room interface was the main display center for the learning media that teachers and students used during the teaching and learning process. In this interface, the system presented a digital space depicting the classroom atmosphere, with a visual background that could be changed to suit the learning needs presented in the interface, as presented in Figure 1.

**Figure 1***Frame Room Interface*

As presented in Figure 1, the frame room also functioned as a consolidator of all features accessible to deaf students, including ASR-generated text and animated sign language characters. The frame room interface became the most central component in interactive learning media activities. It allowed teachers or students to select the type of classroom background used as the background in the learning media. The home button displayed a selection of background images allowing to select and change the visual appearance of the digital classroom based on the ongoing learning context, such as a laboratory, classroom, or garden setting. The purpose of this feature was to provide a dynamic learning experience and helped align the visual atmosphere with the theme of the material being taught, especially in supporting deaf students' understanding through strong and relevant visual elements.

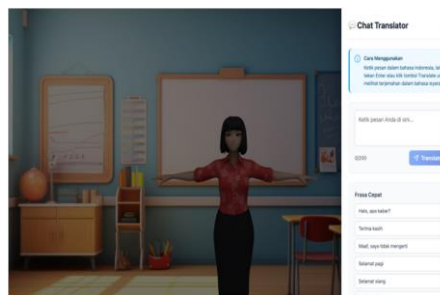
**Figure 2***Text Translation Feature Interface*

Figure 2 presents the text translation feature interface which was designed to allow teachers to easily input text, then it was automatically translated into sign language animations. This feature provided a text input field that teachers could fill in with sentences or words they wish to convey to deaf students. Once the text was inputted, the system matched it to a dictionary of animation assets compiled based on Indonesian Sign

Language. Then, the translation was visualized through animated sign language characters in real time on the learning screen. It was helpful for teachers who had not yet mastered sign language, and allowed for more interactive and inclusive learning

### Figure 3

#### *ASR Feature Interface*

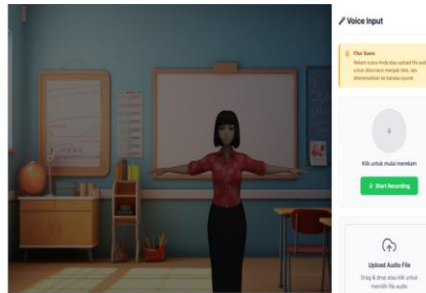


Figure 3 is an Automatic Speech Recognition (ASR) feature for translating voice into sign language animations. It was designed to transform voice into transcribed text. It was done by clicking the Mic button and then began speaking to convey learning material or instructions. After finishing speaking, the teacher pressed the Submit button, and the ASR system automatically processed the voice into transcribed text displayed on the screen. In addition, the text can be reviewed first by the teacher to be adjusted or corrected. This feature allowed teachers to communicate efficiently with deaf students without typing manually, and strengthened student accessibility and engagement through the automatic conversion from voice to visual sign language.

### Figure 4

#### *Learning Video Interface*



As shown in Figure 4, it was designed to optimally support the independent learning process for deaf students. Through this interface, students could easily access a list of learning videos provided by the teacher.

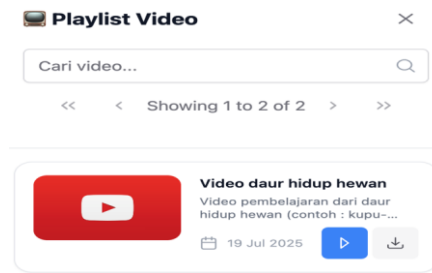
**Figure 5***List of Learning Video*

Figure 5 shows the list of videos that had been transcribed previously using the ASR system, in which the audio from the video narration was converted into text, then stored and adapted to the context of the material. This feature was the synchronous integration of the video, transcribed text, and sign language animation. As the video played, the system automatically called up an animated sign language character based on the words or sentences contained in the transcribed text.

**Figure 6***ASR Interface from Learning Videos*

Figure 6 illustrates the virtual teacher which explained the learning material from the video being played with sign language animation. It assisted the deaf students to learn more independently, flexibly, and still received explanations.

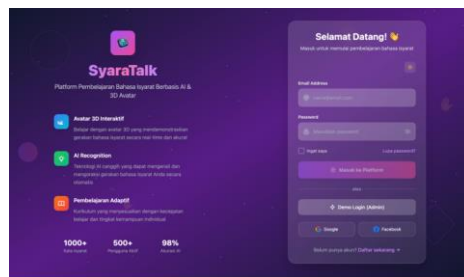
**Figure 7***Login Page*

Figure 7 shows the login page of the learning media. It required filling in the email address and password.

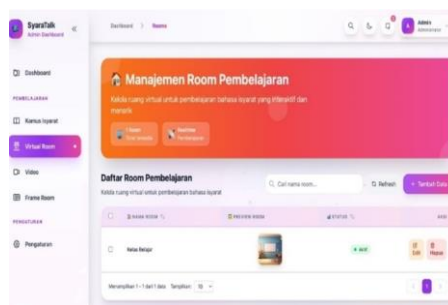
**Figure 8***Dashboard Interface*

Figure 8 shows the dashboard interface provided clear navigation options for important functions such as managing classrooms, managing the asset dictionary, managing learning videos, and accessing the main learning page. The use of visual icons and text menu labels made it easier to identify the function of each menu. Several elements presented on the Dashboard page include a left-hand side menu for accessing data management features (sign dictionary, managing class backgrounds, managing learning videos) and class frame rooms and settings. In addition, it also presented information on the number of active users, the number of sign language words, the number of learning videos, and the number of virtual rooms presented in card information to make it easier for users to monitor information.

**Figure 9**  
*Classroom Management Interface*

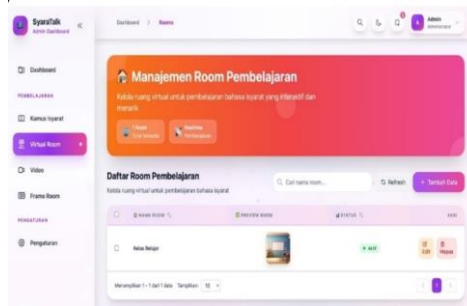


Figure 9 shows the interface of classroom management. In this feature, teachers were able to add new backgrounds by selecting an image file from their device, then entering the room name and determining whether it is active or inactive.

**Figure 10**  
*Addition Class Room Interface*

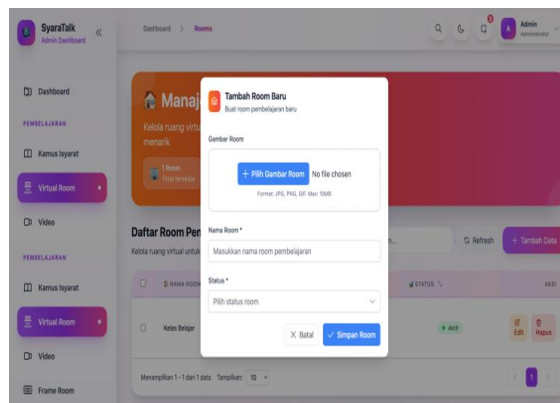
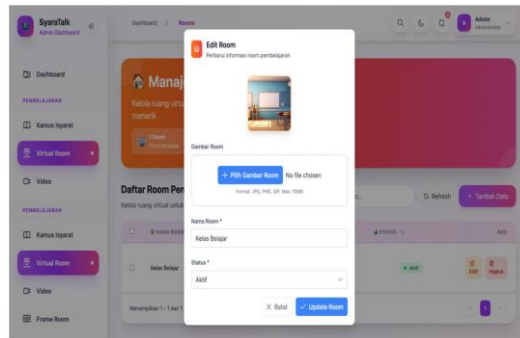


Figure 10. shows the list of added backgrounds that were displayed in a grid or table format in this interface, each displaying a thumbnail of the background image, the room name, and its status.

**Figure 11***Edited Room Interface*

In this feature as presented in Figure 11, teachers were allowed to delete class room data by clicking the Delete icon (trash can image) to delete the class room data from the database by selecting the Delete button in the confirmation window.

**Figure 12***Interface of Deleted Room Confirmation*

Figure 12 shows the deleted room confirmation to make sure it is deleted. This interface prioritized image preview visualization and display responsiveness, allowing users to recognize content simply by viewing its thumbnails. Data input validation was also implemented to ensure image files are in the appropriate format (e.g., .jpg, .png) and that room names were not empty. With flexible classroom room management, teachers could create a more engaging and dynamic digital learning environment.

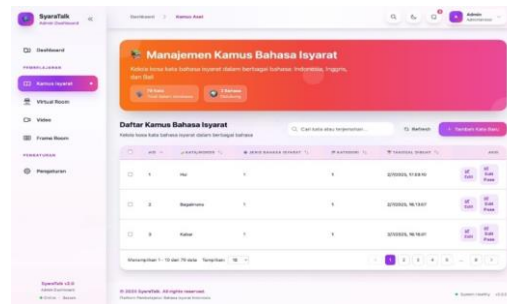
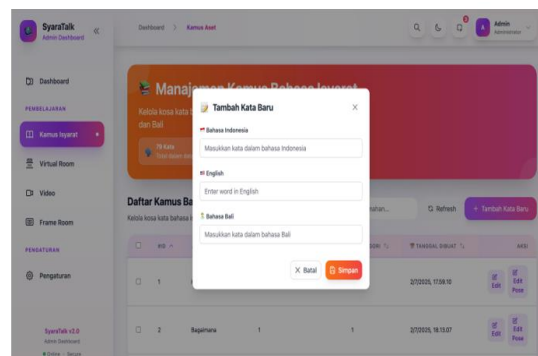
**Figure 13***Asset Dictionary Management Interface*

Figure 13 shows the asset dictionary management interface. It was developed to allow teachers to manage sign language animated character assets, as the main component in translating text generated by Automated Speech Recognition (ASR) into visual form. Each saved asset data was displayed in a table or gallery, with columns for asset name, animation file, and language initials. Teachers could easily search or sort asset data, as well as edit or delete asset data if necessary.

**Figure 14***Animation Addition*

As shown in Figure 14, teachers could add new animation assets by uploading a character animation file and then entering keywords or initials in Indonesian and English that would serve as a callback to the animation.

**Figure 15**

*Asset Dictionary Edit Interface*

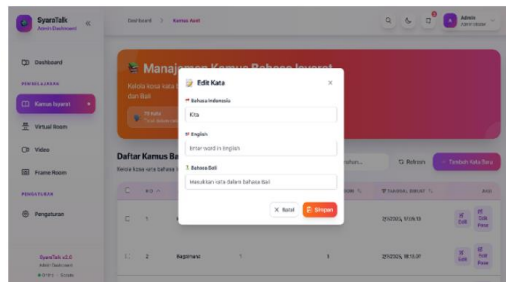


Figure 15 shows the editing feature. The interface for editing asset dictionary data was developed to help teachers update information on previously saved sign language character animation assets.

**Figure 16**

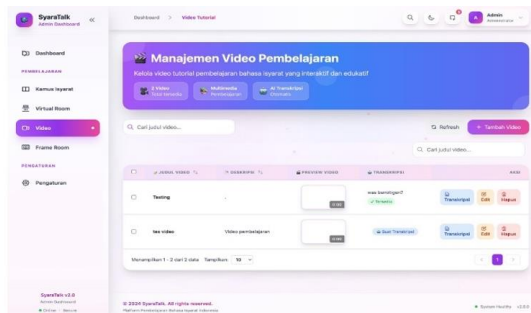
*Asset Dictionary Data Deletion Confirmation Interface*



Figure 16 shows the deletion button. It was developed to remove the asset dictionary data from the database by selecting the Delete button on the confirmation window.

**Figure 17**

*Learning Video Data Management Interface*



As shown in Figure 17, it was developed to support teachers in uploading learning materials, such as videos, that students could use for self-directed learning. Teachers could add videos and know the list of uploaded videos, complete with buttons to edit, delete, and perform voice transcription. Especially, on the transcription button, to be able to use learning media with ASR transcription and sign language animation integration, it can be accessed by scanning the following QR Code.

In this development stage, the learning media were then tested through validation by content experts and media experts using the Content Validity Ratio (CVR) instrument to measure the level of appropriateness and feasibility of the media. The CVR values obtained reflect the alignment of the content with the curriculum, the feasibility of information presentation, and the effectiveness of the user interface design in enhancing the understanding of deaf students. Based on the CVR calculation, a CVR value of 1.00 was obtained for all indicators. This value is higher than the minimum significant CVR threshold for five experts, which was 0.99. Therefore, all indicators were considered valid in terms of the Presentation Design, Interaction Usability, Accessibility, and Reusability aspects.

### **3.4 Implementation**

In the implementation stage, the learning media with Real-Time ASR Transcription and Sign Language Animation was carried out in a field trial at SLB Negeri 1 Gianyar involving several teachers and deaf students. The implementation stage was carried out by applying the learning media with Real-Time ASR Transcription and Sign Language Animation at SLB Negeri 1 Gianyar in teaching and learning activities involving 22 deaf students. During the trial, the deaf students interacted with the animal life cycle material covered in developed learning media. In addition, students and teachers responses. The practicality assessment using the System Usability Scale (SUS) was used by students to measure the ease of use and comfort of interaction with the learning media. It showed the average score of 64.20 from users, which was categorized into the good category. These results indicate that students felt comfortable and assisted in understanding the material through the combination of transcription text and sign language animation. On the other side, the result of questionnaires done by teachers showed that the learning media obtained an average feasibility score of 92.39%, which was categorized

into the very feasible category. It showed that the developed media was considered highly useful, effective in presenting material, and had an attractive and functional appearance.

### 3.5 Evaluation

In the evaluation stage, pretest and posttest was conducted to examine the developed learning media involving 22 students. Then, the result of the test was examined using inferential statistics as follows.

**Table 1**

*Paired Samples Statistics*

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre Test	17,09	22	1,797	,383
	Post Test	22,55	22	1,945	,415

Table 1 shows the descriptive statistics results of the pretest and posttest. It showed that there was a difference in mean score between pretest and posttest.

**Table 2**

*Paired Samples Correlations*

		N	Correlation	Significance One-Sided p	Two-Sided p
Pair 1	Pre Test & Post Test	22	,421	,025	,051

Table 2 shows there was a low correclation about 0.421 between pretest and posttest.

**Table 3**

*Paired Samples Test*

	Paired Differences	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Significance	
					Lower	Upper			One-Sided p	Two-Sided p
Pair 1	Pre Test - Post Test	--5,455	2,017	,430	-6,349	-4,560	-12,683	21	,000	,000

Table 3 shows the t-value of 12,683 with df about 21 and p-value (2-tailed) 0,000. It indicated that there were significant differences between pretest and posttest scores.

**Table 4**

*Paired Samples Effect Sizes*

		Standardizer <sup>a</sup>	Point Estimate	95% Confidence Interval		
				Lower	Upper	
Pair 1	Pre Test	-Cohen's d	2.017	-2.704	-3.610	-1.784
	Post Test	Hedges' correction	2.093	-2.606	-3.479	-1.719

a. The denominator used in estimating the effect sizes.

Cohen's d uses the sample standard deviation of the mean difference.

Hedges' correction uses the sample standard deviation of the mean difference, plus a correction factor.

Table 4 shows a Cohen's d value of -2.017, which was categorized into the category of a very large effect size, indicating a strong influence of the use of media on improving the learning outcomes of deaf students. Based on the SPSS analysis results, the average pretest score was 17.09, and the average posttest score was 22.55. The average difference of 5.45 indicates an improvement in learning outcomes after using the learning media.

#### 4 DISCUSSION

The present study has successfully developed learning media with real-time ASR transcription and sign language animation for deaf students. The developed learning media are valid, feasible, and effective for implementation in the learning process for deaf students. It is because the developed media have met the needs of the students. It is done by conducting the need analysis. As stated by (Ekayati et al., 2020), need analysis is a way to examine what is expected and what happens with the existing condition. From this analysis, the gaps or problems happened in the learning process. As revealed in the present study, the deaf students need to have learning media that is easily accessed by the in the learning process. In addition, the provision of learning media in the learning process can help students to visualize the information. In that regard, learning media become students' needs. When the learning media is provided, it can fill the gap for the learning media in the learning process. Besides, (Puspita & Nurhalim, 2021) also argue that needs analysis can assist individuals to find solutions in improving performance. It can befrom the present study that the provision of the learning media can assist students in the learning process.

It directs students to have better performance due to the assistance of the learning media. They can access it, and it helps them to understand the materials. When they understand the materials, they can perform as it is expected. Furthermore, (Dewi & Qamariah, 2023) add that the purposes of needs analysis are to identify the needed skills, gather information on difficulty, and identify the characteristics of the students. When the needs analysis is conducted and fulfills the purposes, it can exercise students' skills, cope with the problems encountered during the learning process, and meet the characteristics of the students. Therefore, the learning media that is developed through need analysis is beneficial and impactful for teachers and students in the learning process.

In this era, the integration of technology in developing learning media is needed since the learning process requires the use of technology nowadays. As stated by (Zaki, 2020), the use of technology also supports conducting digital or online learning. It is beneficial for students who can access the material online. They can learn it without the presence of the teacher in the learning process. As a result, students can get more exercise by themselves, which leads them to have more exposure to their knowledge. In addition, (Maria et al., 2019) add that the learning media in the learning process are used to stimulate students' minds and feelings. As developed in the present study, the learning media is developed into a video that is attractive for students to understand the content visualized in the video. It can be concluded that learning media that is integrated with technology can provide an attractive learning atmosphere, as expected in the current situation.

The developed learning media is effective for the deaf students since it is designed using ASR. As stated by (Sudarma et al., 2021), digital content can help students remember and understand lesson materials during independent learning. Every instruction delivered by the teacher through audio will be automatically transcribed by the ASR system, which is then visualized in the form of sign language. Moreover (Zhang et al., 2023) and (Aji & Aeman, 2023) state that ASR technology is used as a more natural interaction technology between humans and computers. As revealed in the present study, the learning media with ASR can be effective to improve learning outcomes of deaf students. It is because they are assisted by the ASR to transcribe the audio and visualized in the form of sign language, which is helpful for the deaf students. The result of the present study is also similar to the previous research, as done by (Azzahra et al., 2025) and (Aditya et al., 2022) in which learning media integrated with technology can be interactive for deaf students, which

attracts students to join the learning process attentively and improves their learning outcomes.

## 5 CONCLUSION

This study concludes that learning media based on a real-time ASR transcription process and sign language animation for deaf students has been successfully developed. The developed learning media are valid, feasible, and effective to improve learning outcomes of the deaf students. The study implies that the developed learning media can be implemented for deaf students in understanding the information in the learning materials that they learn.

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### Authors' Contribution

All authors contributed equally to the development of this article.

### Data availability

All datasets relevant to this study's findings are fully available within the article.

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